State of Alaska

DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF SPILL PREVENTION AND RESPONSE

CONTAMINATED SITES PROGRAM

RISK ASSESSMENT PROCEDURES MANUAL

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RISK ASSESSMENT PROCEDURES MANUAL
TABLE OF CONTENTS

APPENDIX B FIGURES:

TABLES

ACRONYMS

AAC	Alaska Administrative Code
ACL	Alternative Cleanup Levels
ADF&G	Alaska Department of Fish and Game
ADEC	Alaska Department of Environmental Conservation
ADHSS	Alaska Department of Health and Social Services
ALM	Adult Lead Model
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency of Toxic Substances and Disease Registry
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BERA	Baseline Ecological Risk Assessment
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
COPEC	Compounds of Potential Ecological Concern
CSM	Conceptual Site Model
DQO	Data Quality Objective
DRO	Diesel-Range Organics
ECAO	Environmental Criteria and Assessment Office
EEC	Estimated Environmental Concentration
EPA	Unites States Environmental Protection Agency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
GRO	Gasoline-Range Organics
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
IUR	Inhalation Unit Risk Factor
L/day	Liters per Day
LD_{50}	Lethal Dose, 50% of the Population
LOAEL	Lowest Observed Adverse Effect Level
LOEL	Lowest Observed Effect Level
m^3/day	Cubic Meters Per Day
MF	Modifying Factor
mg/m^3	Milligrams Per Cubic Meter
MRLs	Minimal Risk Levels
NPL	National Priorities List
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level

NOEL	No Observed Effect Level
NPDES	National Pollutant Discharge Elimination System
ORIA	Office of Radiation and Indoor Air
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PbBs	Blood-Lead Concentrations
PPRTVs	Provisional Peer-Reviewed Toxicity Values
PRGs	Preliminary Remediation Goals
QAPP	Quality Assurance Project Plan
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
RfD_i	Inhalation Reference Dose
RME	Reasonable Maximum Exposure
RP	Responsible Person(s)
RPF	Relative Potency Factor
RRO	Residual-Range Organics
RSL	Regional Screening Levels
SF	Slope Factor
SF_d	Dermal Slope Factors
SF_i	Inhalation Slope Factors
SF_o	Oral Slope Factors
SLERA	Screening Level Ecological Risk Assessment
SQL	Sample Quantitation Limit
TAL	Target Analyte List
TCCR	Transparency, clarity, consistency, and reasonableness
TCL	Target Compound List
TRV	Toxicity Reference Value
µg Pb/dL	Micrograms of Lead Per Deciliter of Blood
$\mu g/m^3$	Micrograms Per Cubic Meter
UCL	Upper Confidence Limit
UF	Uncertainty Factor
URFs	Unit Risk Factors
WOE	Weight of Evidence

1.0 INTRODUCTION

1.1 Development of Guidelines

This manual provides risk assessment procedures for use in preparing human health and ecological risk assessments under the Oil and Other Hazardous Substances Pollution Control site cleanup rules, 18 Alaska Administrative Code (AAC) 75.300 – 18 AAC 75.390, and the Underground Storage Tank regulations, 18 AAC 78. The purpose of performing site-specific risk assessments in accordance with this guidance is to:

- ✓ Determine the baseline risk posed by contamination.
- ✓ Provide a consistent and technically defensible approach for all sites.
- ✓ Expedite review of risk assessments.
- ✓ Minimize revision and resubmittal of risk assessment documents, thereby reducing time and costs to responsible person(s) (RP).
- ✓ Provide the basis for preparation of alternative cleanup levels (ACLs).
- ✓ Assist in the site remediation decision-making process.
- ✓ Identify when the Alaska Department of Environmental Conservation (ADEC) and other stakeholders must be consulted.

This manual provides risk assessment procedures for use in the remediation and cleanup of contaminated sites in Alaska. It also provides users with a single resource point for requirements and technical resources necessary to complete risk assessments. Regional or national risk assessment guidance from the United States Environmental Protection Agency (USEPA) must be used where guidance is not provided by ADEC. However, the remoteness of many Alaska sites, the seasonal extremes of Alaska's climate, the diverse geography, and the unique subsistence lifestyles of many Alaskans combine to make Alaska risk assessments different than risk assessments prepared for typical sites in the continental United States.

The lead agency responsible for approving or directing the risk assessment must be consulted before developing a risk assessment. Risk assessments performed for other purposes than those stated above or prepared under the auspices of other state or federal regulations will likely have different requirements and guidance. For example, if a risk assessment is performed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), a National Pollutant Discharge Elimination System (NPDES) permit application, an Air Quality Emissions permit application, or a Department of Transportation land transfer, the appropriate agency or department with final approval authority over the risk assessment must be contacted to determine if a risk assessment under 18 AAC 75 will also satisfy that program's requirements.

1.2 Risk Assessment and Risk Management

Regulatory actions taken at Alaska contaminated sites require an integration of two distinct processes – risk assessment and risk management.

Risk assessments organize and interpret technical information for use by decision makers. Risk assessment is the scientific process of evaluating the toxic properties of compounds and the conditions of human and ecological exposure to determine the likelihood that an exposed population or ecosystem will be adversely affected. This manual provides instruction in preparing a site-specific risk assessment. The process relies on available, reputable scientific information, and conservative judgments in the case of uncertainty.

Risk management is the process by which risk assessment results are combined with other site information to make decisions about risk reduction. In addition to considering the human health and ecological risk assessment data, risk management takes into consideration technical feasibility, cost, political and social acceptability, and the impact of proposed alternative remedial actions. This manual does not provide guidance on the risk management decisions that must be made by ADEC.

1.3 The Risk Assessment Process

In general, risk assessments prepared for the ADEC Contaminated Sites Program assess risk to current and future receptors at or near the site based on current conditions. These assessments do not consider either current/future remediation or institutional controls. Figure 1 (see Appendix B) outlines the steps of the risk assessment from the initial scoping meeting to risk management decisions, including development of ACLs. Risk assessment is a tool used to assist risk managers in determining ACLs based on site-specific factors. Any level of contamination left on site above a soil or groundwater cleanup level (18 AAC 75.341 and 18 AAC 75.345, respectively) as result of a risk assessment may potentially be considered an ACL. ADEC's review of deliverables and required approvals are both highlighted in Figure 1.

The ecological risk assessment process includes additional steps and deliverables (see Figure 2, Appendix B). The additional steps are intended to quickly identify sites with little or no potential for ecological impacts, so that unneeded and costly evaluation is avoided. It is possible that an ecological risk assessment may not be needed at every site where a human health risk assessment is conducted. Subsection 4.1 describes the four main steps in the ecological risk assessment process.

For both assessments ADEC requires the use of reasonable maximum exposures (RMEs) for all risk characterization calculations. RME is defined as the highest exposure that is reasonably expected to occur at a site. The intent of the RME is to estimate a conservative exposure scenario that is within range of possible exposures (yet well above the average case) and to avoid estimates that are beyond the true distribution.

1.3.1 When to do a Risk Assessment

Once site characterization data gaps are adequately addressed, a risk assessment can be used to identify potential risks at a site, communicate those risks, and/or develop ACLs at a site based on site-specific factors. A risk assessment must be performed when the RP wishes to develop ACLs by substituting site-specific exposure factors for the defaults used to develop the cleanup levels in the 18 AAC 75 tables, or using any site-specific physical factors or models. A risk assessment may also be necessary if additional complete pathways are identified other than those

protected by the cleanup levels in the 18 AAC 75 tables. For instance, inhalation of volatile contaminants in indoor air, ingestion of wild foods, exposure to fugitive dusts, or exposure to aquatic or terrestrial ecological receptors that are not protected under the cleanup levels in the 18 AAC 75 tables. Therefore, if one of these pathways is complete at a site, a risk assessment may be warranted. Subsection 3.5 of ADEC's *Policy Guidance on Developing Conceptual Site Models* (ADEC 2017) indicates exposure pathways used to develop clean up levels.

1.3.2 Risk Assessment Requirements

Risk assessment must be conducted by individuals experienced in the technical and regulatory aspects of risk assessment and in consultation with ADEC's risk assessment staff. At a minimum, for human health risk assessments, the RP must submit the following documents to ADEC for review and approval:

- Human exposure assessment scoping and human health preliminary Conceptual Site Models (CSMs).
- Ecological scoping evaluation and ecological health preliminary CSMs.
- Risk Assessment Work Plan.
- Risk Assessment.

For ecological risk assessments, a brief scoping evaluation is the first deliverable that must be submitted by the RP. Additional deliverables may or may not be necessary based on the results of the ecological scoping evaluation. Further details are provided in subsection 4.1.

A draft version of each document must be submitted to ADEC for review and approval before submittal of the final version.

1.3.3 Risk Assessment Reviews

Draft and final CSMs, work plans, risk assessments, and other deliverables must be reviewed by ADEC risk assessment staff or a contracted third party selected by ADEC. Taking into account the technical comments on the risk assessment document, ADEC will either approve the document, return it to the RP for comment resolution, revision, and resubmittal, or reject the document. In most cases, ADEC will request a written response to comments and a final version of the document, incorporating the agreed upon changes. In some cases, draft documents and an addendum documenting changes will suffice to make a document final. ADEC risk assessment staff must be consulted on the appropriate report needs.

At ADEC's discretion, the risk assessment review process may include a public advisory committee, a technical assistance group, USEPA staff, or other state and federal agencies. All interested and affected parties must be identified in the initial scoping meeting for the risk assessment.

1.4 Public Participation

ADEC will seek public participation regarding activities conducted under the site cleanup rules, using methods that ADEC determines to be appropriate for seeking public participation, per 18 AAC 75.325(j). This may include public comment when ACLs are proposed based on a site-

specific risk assessment (18 AAC 75.340(f)(1) and 18 AAC 75.345(b)(2)). Public comment is a formal process, which includes the following:

- Providing public notice to the people of an affected area that ADEC is seeking comments. The minimum requirement is that the public notice must be published in local newspapers and on the State of Alaska website.
- Establishing a public comment period during which ADEC will accept comments. The public comment period usually lasts 15 or 30 days. Comments can be received in writing, by fax, or via e-mail.
- Completing a responsiveness summary of written responses to the received comments.

Consultation with the public is required when making a commercial/industrial land use designation for developing ACLs (18 AAC 75.340(e)(3)(A)), and when alternative points of compliance are established for groundwater hydrologically connected to surface water (18 AAC 75.345(g)).

2.0 PLANNING

Planning for the risk assessment must begin as early as possible in the site investigation stage. Early planning for a risk assessment will save money and resources during the site investigation and reduce the potential need for collection of additional data.

The planning stage for a risk assessment involves creation of preliminary CSMs and assessing data usability. CSMs characterize the distribution of contaminant concentrations across the site and identify all potential exposure pathways, migration routes, and potential receptors at a site. Information on CSMs is given in ADEC's *Policy Guidance on Developing Conceptual Site Models* (ADEC 2017). The risk assessment scoping meeting exercise allows for the development of the CSMs in consultation with ADEC and therefore lends greater efficiency to the work plan review process. Data usability is discussed in the data evaluation subsection (subsection 3.1). These components of the risk assessment are discussed during the scoping meeting and completed in the work plan.

The problem formulation phase (subsection 4.2) of the ecological risk assessment must be completed during planning and scoping. Fundamental components of problem formulation must be discussed during the planning of an ecological risk assessment. These components are discussed in subsection 4.2.1.

2.1 Scoping Meeting

The purpose of a scoping meeting is:

- To define the purpose and limitations of the risk assessment.
- To identify management goals, key issues such as current and future land use, and policies needing to be addressed.
- To share current knowledge of the site.
- To identify exposure and assessment areas.
- To discuss key exposure and toxicity assumptions.
- To develop preliminary CSMs.
- To identify and evaluate the adequacy of available data.
- To discuss work plan requirements for the human health and ecological section of the risk assessment.

A checklist of items that must be discussed during the scoping meeting, as applicable, is included in Appendix A. This checklist can also be used to develop an agenda for the meeting. Risk assessors must come to the scoping meeting prepared to discuss each of the topics listed above and in the checklist, as appropriate for the site. The meeting must focus on ADEC concurrence with assumptions, CSMs, proposed process, and schedule. Communication between ADEC and the RP is essential throughout the risk assessment process. The scoping meeting establishes lines of communication as well as determines the document deliverable schedule.

2.2 Risk Assessment Work Plan

The risk assessment work plan describes the tasks and methods that will be used to assess risk to human health and the environment. It must consider all potential exposure media including soil, groundwater, sediments, surface water, air, and biota as applicable, and describe how risk from exposure to each media will be assessed.

Human health risk assessment work plans shall include the following:

- Site description, figures, and data summaries from site investigation(s).
- Description of land use and exposure areas.
- Data evaluation to include review of adequacy of detection limits.
- Evaluation of contaminant fate and transport.
- All proposed exposure assumptions or citations.
- Human health CSMs.
- All proposed toxicity data or citations.
- Human health risk screening levels.
- Data evaluation and an initial list of contaminants of potential concern (COPCs).
- Discussion of data gaps and a plan for data collection, if necessary.
- Descriptions and justification for all proposed modeling.
- Methods for calculating risk and ACLs.

Ecological risk assessment work plans shall include the following:

- Site description, maps, figures, methods of data collection, and data summaries from site investigation(s).
- Identification of potential exposure pathways, ecological endpoints, and receptors or receptor groups.
- Evaluation of contaminant fate and transport.
- Ecological scoping evaluation documentation.
- Ecological health risk screening evaluation.
- Identification of assessment endpoints – commonly derived from management goals.
- Ecological CSM.
- Data evaluation to include review of adequacy of detection limits.
- Initial list of Contaminants of Potential Ecological Concern (COPECs).
- Discussion of data gaps and plans for data collection, if necessary.
- Analysis approach – including criteria for measurement of effects, ecological benchmarks, and testable hypotheses.
- Methods for determining risk-based concentrations and calculating toxicity reference values (TRVs).
- Explanation of proposed exposure assumptions or citations.
- References for proposed toxicity data or citations.

- Description and justification for all proposed modeling.

All exposure assumptions and parameters must be provided in the work plan. If parameter values are not available, detailed descriptions of the methodology and literature citations that will be used to develop the exposure parameters must be included. For instance, if the site-specific fish ingestion rate is not known at the time of the work plan, it must explain whether interviews, community surveys, literature values, or other data will be used to estimate fish ingestion rate and give a detailed description of how this is to be done. ADEC in coordination with the responsible person will consult with the Alaska Department of Health and Social Services (ADHSS) and/or the Agency for Toxic Substances and Disease Registry for the appropriate evaluation of the subsistence food pathway. It may be necessary for the risk assessor to refine the CSM, list of COPCs, exposure pathways, and/or receptors presented in the work plan as additional information is obtained.

2.3 Submittal Requirements

The following list details the deliverables required to be submitted to the ADEC project manager for human health risk assessments:

- CSM (one electronic copy in portable data file (pdf) format) to include scoping forms. (see Policy Guidance on Developing Conceptual Site Models (ADEC, 2017))
- Risk Assessment Work Plan (one electronic copy in pdf format)
    - o numerical data and screening levels in Microsoft Excel.
    - o table of all default and site-specific exposure assumptions.
    - o table of all toxicity data for COPCs.
    - o all model inputs and assumptions as appropriate.
- Risk Assessment (one electronic copy in pdf format)
    - o numerical data in Microsoft Excel.
    - o risk screening evaluation tables in Microsoft Excel.
    - o Reasonable Maximum Exposure (RME) calculations in Microsoft Excel or as ProUCL output (note: all summary and data input pages must be included).
    - o risk calculations tables in Microsoft Excel.
    - o all modeling inputs and outputs.
    - o ACL calculations in Microsoft Excel.

For ecological risk assessments, the first submittal must be the scoping evaluation, with preliminary screening. If warranted based on site conditions, a Screening Level Ecological Risk Assessment (SLERA) may be required, and a Baseline Ecological Risk Assessment Work Plan and Baseline Ecological Risk Assessment (BERA) as warranted.

Project-specific submittal requirements need to be determined with the ADEC project manager and ADEC risk assessor.

2.4 Deterministic and Probabilistic Evaluations

Deterministic risk assessments express risk as a single numerical value which must represent the RME. As such, uncertainty and variability in deterministic risk assessments are discussed in a qualitative manner. In general, deterministic risk assessments are adequate for the purpose of determining risk and providing a basis for calculating ACLs.

ADEC will also consider the use of probabilistic risk assessment techniques for human health and ecological risk assessments. Probabilistic risk assessments assign a distribution to exposure factors. This results in risk being expressed as a probabilistic distribution. This approach allows uncertainty and variability to be expressed quantitatively. Probabilistic risk assessment is data intensive, and it must not be done unless there is high quality data available to characterize the distribution of contaminants in exposure media and the behavior patterns of receptors at or near the site. Data would constitute, at a minimum, sufficient contaminant samples in each media, appropriate to statistically characterize the distribution of contamination. It would also require a source of information about activity patterns near the site that was comparable in quality to studies in USEPA's Exposure Factors Handbook (2011. For guidance on performing a probabilistic risk assessment, please consult, *Risk Assessment Forum White Paper: Probabilistic Risk Assessment Methods and Case Studies* (EPA, 2014a).

Risk assessment planning must be a tiered approach that progresses from simpler to more complex analyses as the situation requires. Use of probabilistic risk assessment for human health or ecological evaluation must be discussed with ADEC on a case-by-case basis during the scoping meeting.

3.0 HUMAN HEALTH RISK ASSESSMENT

The human health risk assessment (HHRA) methodology in this section integrates federal and state requirements with site-specific information to provide a framework for performing an HHRA at an Alaska contaminated site. *Risk Assessment Guidance for Superfund* (USEPA, 1989) or other USEPA guidance must be consulted if ADEC does not provide guidance for aspects of the HHRA process. Additional guidance and information on risk assessment can be obtained from Interstate Technology Regulatory Council.

EPA Guidance: Data Evaluation

- ☐ *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A) – Interim Final* (USEPA, 1989a)
- ☐ *Guidance for Data Usability in Risk Assessment (Part A) – Final* (USEPA, 1992b)
- ☐ *Data Quality Objectives Process for Hazardous Waste Site Investigations* (USEPA, 2000c)
- ☐ *Guidance for Data Quality Assessment: Practical Methods for Data Analysis* (USEPA, 2000d)

3.1 Data Evaluation

Data evaluation is the process for identifying if data is of sufficient quality and quantity to determine concentrations of COPCs in a risk assessment. This must be done **before** screening for COPCs.

3.1.1 Data Usability

Only sampling methods that give accurate, chemical-specific concentrations are useful. In general, field-monitoring tests do not provide data of sufficient quality to be used for risk assessment purposes. Consultation with the ADEC project manager and technical staff in developing the sampling plan for the site investigation is recommended to assure data are collected that are appropriate for risk assessment purposes.

The available sampling data, including any historical data, must be evaluated to assess the type, quantity, and quality of data in order to verify that the planning objectives, Quality Assurance Project Plan (QAPP) components, and sample collection procedures were satisfied, and that the data are suitable for its intended purpose.

For data to be considered adequate for a risk assessment, the following criteria must be met:

- Analytical data sufficient for adequate site characterization must be available.
- Data must have been collected consistent with ADEC and USEPA guidance.
- Sampling and analytical procedures must give accurate chemical-specific concentrations.
- Validated analytical laboratory data is required.
- Method detection limits and sample quantitation limits to the extent practicable should be below screening criteria.

- Qualified data must be appropriately used and explained in the uncertainty section (i.e., discussion on potential bias from qualified data and how it might result in the over or under estimation of risk).
- Rejected data **shall not** be used for risk assessment purposes. The risk assessment data usability criteria listed below must be assessed during scoping for the risk assessment. Mitigation for inadequate data must be agreed upon with ADEC.
- **Data Sources** – Data must be from comparable sources (i.e., analytical methods, areas of concern, sampling methodologies).
- **Documentation** – Deviations from the sampling analysis plan (SAP) and standard operating procedures (SOPs) must be documented so that risk assessors are aware of any potential limitations in the data.
- **Analytical Methods** – The method chosen must test for the compounds at detection limits that are at or below applicable screening levels, or applicable or relevant and appropriate requirements (ARARs).
- **Data Quality Objectives** – Data quality objectives (DQOs) according to the *Data Quality Objectives Process for Hazardous Waste Site Investigations* (USEPA, 2000c) for analytical data must be met. Components of DQOs are listed below:

    - Precision – if the reported result is near the concentration of concern, it is necessary to be as precise as possible in order to quantify the likelihood of false negatives and false positives.
    - Accuracy – inaccurate data caused by contamination or uncalibrated instruments will bias results of the risk assessment.
    - Representativeness – sample data must accurately reflect the site characteristics to effectively represent the site's risk to human health and the environment. Hot spots and exposure area media must have representative data.
    - Completeness – completeness for critical samples must be 100%.
    - Comparability – risk levels generated in a quantitative risk assessment may be questionable if incompatible data sets are used together.

- **Data Review** – Use of preliminary or partially reviewed data is **not** recommended. A full data quality review is required.
- **Reports** – A data review report that includes evaluation of the adequacy of the analytical quantitation limits, demonstration that DQOs have been met as described above, and a narrative discussing any qualified data and potential impacts resulting in uncertainties in the risk estimates must be provided.

3.1.2 Consistency with Conceptual Site Models

Sampling plans must be consistent with the site-specific conceptual site model and must give adequate coverage to exposure media of concern.

Sometimes it is difficult or expensive to obtain samples of exposure media, subsistence foods, or it is difficult to distinguish contaminant concentrations from background. The following recommendations are given to assure that data will support a risk assessment and must be discussed by responsible party, project managers and risk assessors prior to completion of the work plan:

- If vapor intrusion into indoor air from soil or groundwater is a potential pathway, soil gas measurements are typically the easiest to interpret.
- If migration to surface water is a potential concern, pore water data and sediment data may be necessary to determine to what extent contaminants are migrating.
- Mobile organisms used as subsistence foods are problematic to sample. It is difficult to obtain sufficient samples to make conclusions in the face of the typically high variability of contaminant concentrations. Some guidance is provided in the document for sampling subsistence resources, but it is not generally recommended by ADEC. Additional lines of evidence, such as bioaccumulation modeling, may still be required even if tissue data is available.

3.1.3 Potential Contaminants

Potential contaminants are those compounds that were likely used or spilled at the site. Site history and previous site characterization studies must be used to develop the initial list of potential contaminants. Attention must be paid to possible breakdown products of compounds as well. For instance, if DDT is a potential contaminant at a site, it may also be necessary to include its breakdown products, DDD and DDE, as potential contaminants. The list will be further refined based on the steps provided below.

3.1.3.1 Target Analyte List/Target Compound List

At any contaminated site there is the potential for a large number of contaminants to be present. USEPA developed a list of approximately 150 hazardous substances most commonly encountered while implementing the clean water, clean air, and hazardous substance programs. These substances, referred to as the Target Analyte List (TAL) and the Target Compound List (TCL), are those substances that are manufactured and used in the greatest amounts and that are the most toxic.

These lists typically form the initial set of hazardous substances considered during a site investigation. With appropriate information on the history of site operations and previous environmental investigation data, the initial set can be tailored to site conditions by adding site-specific hazardous substances and indicator parameters that could prove to be of interest and by deleting those not likely to be present in any significant quantities. This list of contaminants, coupled with the site-specific CSM, must be used when developing field sampling plans to address data gaps for the HHRA.

3.1.4 Selection of Contaminants of Potential Concern

Screening of site COPCs using commonly agreed upon screening concentrations and protocol is used to identify compounds at a site that need further analysis in the HHRA. Those compounds that exceed screening levels are carried through the HHRA process. A well-developed CSM is needed to properly screen for COPCs. Screening levels must be selected based on the exposure pathways and media identified in the CSM. Refer to ADEC's *Procedures for Calculating Cumulative Risk* (ADEC, 2018b) for special instructions regarding petroleum hydrocarbons, PCBs, dioxins, and lead.

The general steps used to screen for human health COPCs are summarized below and described in detail in the following text:

1. Tabulate the **maximum** concentration of each contaminant detected in each environmental medium.
2. Determine contaminant-specific human health screening level.
3. Compare the **maximum** site concentration to screening level.
4. Eliminate compounds that do not exceed the screening level.
5. Compounds that do not exceed ADEC-approved background concentrations are eliminated from risk characterization but may be retained for discussion in the uncertainty section if they exceed risk based screening values.
6. Identify compounds not eliminated as COPCs and carry-through for qualitative evaluation.

Note that special attention must be paid to any potential data bias when comparing sample results to screening values. For instance, if a result is qualified and considered biased low, then it may not be eliminated as a COPC even though the result is lower than the risk screening level.

If contaminants were not detected, evaluate if detection levels were greater than the screening values. If adequate detection limits are not technically feasible, then conservative alternative concentrations must be considered for the screening process to ensure that no compounds are inappropriately screened out of the HHRA.

Risk based screening levels can be obtained from the most current Regional Screening Levels (RSL) table for Chemical Contaminants based on ADEC screening requirements of a Hazard Quotient (HQ) = 0.1 and cancer risk 1×10^{-6} (see: http://www.epa.gov/region9/superfund/prg/). If compounds are not listed in the RSL table, then the RSL equations can be utilized, incorporating toxicity information from sources discussed in section 3.3.1., along with appropriate chemical specific parameters, applicable climate zone, and a residential exposure scenario. This information can be then be used to develop a screening level corresponding to the non-carcinogenic risk HQ of 0.1 and carcinogenic risk level of 1×10^{-6} for the for the respective media. Initial screening for all sites must be against residential chronic exposure scenarios using a toxicity source derived from the toxicity hierarchy discussed in section 3.3.1. If required information is unavailable for developing a screening value with RSL equations, the compound must be retained for qualitative or an approved quantitative approach evaluation in the HHRA. Consult with the ADEC risk assessment staff in this event.

If additional exposure pathways or media exist, such as ingestion of subsistence foods, inhalation of indoor air, or breast milk, other screening criteria may need to be proposed. The screening criteria must correspond to a HQ = 0.1 or a cancer risk of 1×10^{-6} when default residential exposure assumptions are used. Details for evaluating some of these additional exposure pathways and media are discussed below.

Subsistence Foods: Appropriate risk screening criteria for biota used as subsistence foods must be developed on a site-specific basis and in coordination with ADEC risk assessment staff and the Alaska Department of Health and Social Services (ADHSS) and/or the Agency for Toxic Substances and Disease Registry (ATSDR). Evaluation of the ingestion of subsistence foods exposure pathway is discussed later in Section 3.2.2.3.

Vapor Intrusion: For the evaluation of the vapor intrusion pathway (i.e., inhalation of indoor air) ADEC recommends the use of its *Vapor Intrusion Guidance* (ADEC, 2017).

Contaminants in Breast Milk: Infant consumption of contaminated breast milk shall be considered a potential exposure pathway on a chemical- and site-specific basis.

Fugitive Dust: In general, ingestion of fugitive dust is deemed a protected exposure route under the direct contact to soil pathway. This may not be the case where dust is generated by human activity or where specific fugitive dust compounds of potential concern are present at the site. A list of contaminants commonly considered for fugitive dust concern is presented in the ADEC's *Procedures for Calculating Cumulative Risk* (ADEC, 2018b).

Surface Water Consumption: If ingestion of surface water is a pathway of concern, the groundwater screening levels should be used as risk-based screening levels for surface water. However, water quality standards for surface water (18 AAC 70) must be considered when evaluating a site with surface water contamination to address ecological concerns (see ecological risk assessment section). Water quality standards for applicable fresh and marine water classes must be used. Water quality standards are to be considered ARARs and, therefore, must also be used as screening levels.

Sediment Exposure: If human ingestion or dermal contact of sediment is a complete pathway based on the site- specific CSM, the soil screening levels can be used as risk-based screening levels for sediment as well.

Bioaccumulation in Wild Foods: Bioaccumulative contaminants may be of special concern if people hunt, fish, or gather food on or near the site. If the ingestion of wild foods is a complete pathway at the site, bioaccumulative compounds must be retained as COPCs. Bioaccumulation is defined as the accumulation of chemicals in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, and pore water in the sediment (EPA, 2000b). Bioaccumulative compounds are classified by ADEC as having a bioconcentration factor (BCF) equal to or greater than 1,000 (EPA, 2004d) for organic compounds or log K_{ow} greater than 3.5, or that are identified by USEPA (USEPA, 2000a) as bioaccumulative inorganic compounds. A list of bioaccumulative compounds commonly found

at contaminated sites in Alaska is provided in Appendix C, *Policy Guidance on Developing Conceptual Site Models* (ADEC, 2017).

Natural Background Contamination: Distinguishing site contamination from naturally occurring background concentrations in HHRA is an important part of screening. For further information, see USEPA's guidance *Role of Background in the CERCLA Cleanup Program* (USEPA, 2002d) and *Guidance for Comparing Background and Chemical Concentration in Soil for CERCLA Sites* (USEPA, 2002c). If inorganic contaminant concentrations are less than or equal to the naturally occurring background for the site, then the compound may not need to be retained as a COPC for remedial consideration, but still may yet be considered for its contribution to cumulative risks and risk management decisions. Hence, although naturally occurring compounds may be excluded from the baseline risk assessment, at some sites the risk from naturally occurring background compounds may be included in the baseline risk assessment, presented separately in the uncertainty section from the site-related risks, at the option of the ADEC.

Compounds not eliminated after completing Steps 1 through 5 are retained as COPCs and must be carried through the HHRA for further evaluation. An example of a data summary table is provided as Table A.1 in Appendix A.

3.2 Exposure Assessment

Exposure assessment is the process of determining magnitude, frequency, duration, and route of exposure to chemical or physical agent. The results of the exposure assessment are detailed CSMs and a set of exposure assumptions that, combined with chemical-specific toxicity information, characterize potential risks at the site.

ADEC requires the HHRA to consider both current and future exposure scenarios. The default exposure scenario for which risk assessments shall be performed is an unrestricted residential land use scenario. Prior approval with appropriate justification is required from ADEC to exclude a residential land use scenario along with the consent of each landowner who is affected. All exposure assumptions must be documented and referenced accordingly.

3.2.1 Developing a Conceptual Site Model

Developing a CSM is a critical step in properly evaluating contaminated sites and properly identifying data quality objectives (DQOs). A preliminary CSM must be part of the site characterization work plan and acts as a guide for data collection. The CSM is a comprehensive representation of the site that documents current site conditions. It characterizes the distribution of contaminant concentrations across the site and identifies all potential exposure pathways, migration routes, and potential receptors for further analysis. To properly develop a CSM that indicates complete and potentially complete exposure pathways, see *Policy Guidance on Developing Conceptual Site Models* (ADEC, 2017).

3.2.2 Calculating Chemical Intake

After the CSM is complete, the next step in the exposure assessment is to quantify the magnitude, frequency, and duration of exposure for the populations potentially at risk for each

exposure pathway selected for quantitative evaluation. This step is conducted in two stages; first, pathway-specific intakes are quantified, and second, exposure concentrations at the exposure point are estimated.

3.2.2.1 Pathway-Specific Intakes

The generic ingestion equation and variables for calculating chemical intakes are described below.

$$I = C \times \frac{CR \times EF \times ED}{BW \times AT}$$

Where:

I	=	intake: the amount of chemical at the exchange boundary (e.g., mg/kg body weight/day)
C	=	exposure point concentration in specific media (e.g., milligrams per liter of water)
CR	=	contact rate: the amount of contaminated medium contracted per unit time or event (e.g., liters/day)
EF	=	exposure frequency: describes how often exposure occurs (days/year)
ED	=	exposure duration: describes how long exposure occurs (years)
BW	=	body weight: the average body weight over the exposure period (kg)
AT	=	averaging time: period over which exposure is averaged (days)

The intake equation will need adjustment based on the oral, dermal, or inhalation exposure route investigated.

3.2.2.2 Exposure Assumptions

Each intake variable in the equation can have a range of values. Intake variable values for a given pathway must be selected so that the combination of all intake variables results in an estimate of the reasonable maximum exposure (RME) for the pathway. All specific exposure assumptions must be defined in a table in the work plan and HHRA and their source referenced as appropriate. Table 1 provides exposure factors for common exposure pathways in Alaska. These values may be adjusted with ADEC approval to meet site conditions, as appropriate. There are several sources of information about human activity and behavior patterns, such as USEPA's Exposure Factors Handbooks, the National Human Activity Patterns Study, and published scientific literature. These must be used as a resource when site-specific exposure scenarios are developed. Deviations from information in such resources may be appropriate, but must be defensible and conservative and must be made in consultation with ADEC.

Site-specific application of quantitative bioavailability adjustments in risk assessments is not recommended. A default value of 100% is recommended for all chemicals except arsenic and lead in soil for the baseline risk assessment. A default of 60% for arsenic (EPA, 2012) and the default value used in the Integrated Exposure Uptake Biokinetic (IEUBK) model (EPA, 2009a) for lead in soil is recommended.

Table 1 Summary of Default Exposure Factors

	Resident		Commercial/Industrial Worker		Subsistence User[1]		
Exposure Parameter	**Soil**	**Groundwater**	**Soil**	**Groundwater**	**Soil**	**Groundwater**	**Wild Food**
Exposure Frequency (d/yr)	330/270/200[4]	350	250/200[4]	350	330/270/200[4]	350	365
Exposure Duration (yr)	20 (adult) 6 (child) 26 (combined)	20 (adult) 6 (child) 26 (combined)	25	25	20 (adult) 6 (child) 26 (combined)	20 (adult) 6 (child) 26 (combined)	20 (adult) 6 (child) 26 (combined)
Soil Ingestion Rate (mg/d)	100 (adult) 200 (child)	-	100 (outdoor worker) 50 (indoor worker)	-	100 (adult) 200 (child)	-	-
Groundwater Ingestion Rate (L/d)	-	2.5 (adult) 0.78 (child)	-	2.5	-	2.5 (adult) 0.78 (child)	-
Food Ingestion Rate (mg/kg)	-	-	-	-	-	-	Site-specific[2]
Skin Surface Area Exposed (cm^2) [3]	6,032 (adult) 2,373 (child)	20,900 (adult) 6,378 (child)	3,527	-	6,032 (adult) 2,373 (child)	20,900 (adult) 6,378 (child)	-
Adherence Factor (mg/ cm^2)	0.07 (adult) 0.2 (child)	-	0.12	-	0.07 (adult) 0.2 (child)	-	-
Body Weight (kg)	80 (adult) 15 (child)	-	80	-	80 (adult) 15 (child)	-	80 (adult) 15 (child)
Lifetime (yr)	70	70	70	70	70	70	70

1 – All values are recommended default values. Each parameter may be adjusted, as needed, based on site and/or exposure specific information.

2 – Value can be obtained from ADF&G *Community Subsistence Information System* and must be verified or adjusted, as needed, based on input from the community potentially affected by the site contamination. Ingestion rates obtained from the *Community Subsistence Information System* are developed by averaging harvest and use rates over a year; therefore, if this value is used, an exposure frequency of 365 days must also be used.

3 – Exposed skin surface area may be reduced based on site-specific climate information. For instance, reduction in surface area exposed may be justified in areas that have temperatures below freezing in the winter months. The assumption is that less skin would be exposed during this time period.

4 – Soil exposure frequency is based on the climate zone in which the site is located, consistent with ADEC's *Procedures for Calculating Cleanup Levels* (ADEC, 2018a). Residential and subsistence user soil exposure frequency is 330 d/yr for the over 40-inch zone, 270 d/yr for the under 40 inch zone, and 200 d/yr for the arctic zone. For commercial/industrial workers, the soil exposure frequency is 250 d/yr for the over and under 40-inch zones, and 200 d/yr for the arctic zone.

Reference: *Exposure Factors Handbook* (USEPA, 2011)
Child Specific Exposure Factors Handbook (USEPA, 2008a)
Procedures for Calculating Cleanup Levels (ADEC, 2018a)
Dermal Assessment (USEPA, 2004c)
Supplemental Soil Screening Guidance (USEPA, 2002g)

3.2.2.3 Alaska-Specific Exposure Scenarios

Communities that use wild food on a subsistence basis in some instances have ingestion rates of specific wild food resources significantly different than the default rates recommended by USEPA. The Alaska Department of Fish and Game (ADF&G) developed wild food consumption rates by resource for many communities throughout Alaska. These rates were developed from information on harvest and use of wild food resources, based on survey information. The use rates are found in the *Community Subsistence Information System* or CSIS (ADF&G, 2013). If available, the high-end user rate for the community of interest must be used to estimate ingestion rates for specific resources. Median user values are appropriate if high-end rates are not available. Values from the CSIS must only be used in consultation with the community potentially affected by site contamination. If more appropriate studies or values are available, these values must be used instead. Studies done for the lower 48 states or studies that average subsistence food consumption across vast regions or the state of Alaska are not recommended sources for exposure assessment. Though not mandatory, consultation with the Alaska Department of Health and Social Services (ADHSS) or the Agency for Toxic Substances and Disease Registry (ATSDR) is highly recommended for the appropriate evaluation of the subsistence food pathway. ADEC advises the responsible party to consult with ADHSS and ATSDR during the scoping phase of the risk assessment to discuss their involvement and the level of assistance required to evaluate the subsistence pathway.

3.2.3 Calculating Exposure Point Concentration

Estimation of the concentration of COPC is a key element of the HHRA process for contaminated sites. The exposure point concentration (EPC) represents a conservative estimate of the chemical concentration available across a route of exposure. The EPC is determined for each individual exposure unit within a site. An exposure unit is the area throughout which a receptor comes in contact with an environmental medium for the duration of the exposure.

Exposure Area

For the purposes of risk assessment, the source area is the exposure area. The source area is defined as an evident volume of soil and/or groundwater containing elevated or potentially elevated concentrations of contaminant (horizontal and vertical extent) in comparison to surrounding media. The source area includes the following:

- Area with visible stains, known contamination, and/or obvious releases.
- Area where contaminants have leaked, spilled, migrated, and been disposed.
- Area where sufficient laboratory data indicates elevated concentrations relative to surrounding media.

In addition, contamination from other nearby source areas that have comingled with those from the source area being address must be considered in the exposure assessment; however, the exposure area should not be expanded to include the nearby source area unless specifically approved by ADEC. Source area consideration takes into account not only the direct contact pathway, but also potential migration of contaminants resulting in the completed inhalation and migration to groundwater pathways. This approach provides a conservative means of protecting current and future receptors regardless of future land use. ADEC takes into

consideration volatilization and migration of contaminants in the inhalation and migration to groundwater cleanup levels and therefore any sampling approach must consider them accordingly and demonstrate these pathways are being adequately protected. The Risk Assessment Guidance Part A (RAGS A) discusses contaminant distribution and exposure considerations:

> *In some cases, contamination may be unevenly distributed across the site, resulting in hot spots (areas of high contamination relative to other areas of the site). If a hot spot is located near an area which, because of site or population characteristics, is visited or used more frequently, exposure to the hot spot must be assessed separately. The area over which the activity is expected to occur must be considered when averaging the monitoring data for a hot spot. For example, averaging soil data over an area the size of a residential back yard (e.g., an eighth of an acre) may be most appropriate for evaluating residential soils pathways* (USEPA, 1989a).

However, current, let alone future, land use may not be readily defined at most contaminated sites and this determination is further complicated with the remoteness of sites, subsistence use, and historic or cultural considerations unique to Alaska. Therefore, application of a default exposure unit is **not** appropriate for site characterization or risk assessment.

Each groundwater well must be considered the exposure area for groundwater assessment, whereby the maximum detected concentration in groundwater within the source area shall be used as the EPC.

Exposure Point Concentration

The EPC must be a conservative estimate of the average concentration to which a receptor is exposed over time. The EPC is **not** to be used for COPC screening for soils. In addition, high concentrations within an area must not be "diluted out" by averaging with several lower concentrations over a larger area or outer boundary sampling. Site characterization data is typically focused on identifying and delineating the source area. However, a data set generated solely from characterization data does not exhibit a defined distribution and has a high degree of bias to the lower concentrations (i.e., delineation and extent of boundary), which generally will not produce a 95% UCL that is representative of the source area. A visual and/or geospatial assessment is required to decrease the bias of the representation.

For groundwater, the maximum concentration is used both for screening and risk assessment. See section 3.1.4 for guidance on COPC screening. The EPC is used to assess risk and must be estimated using a 95% upper confidence limit (UCL) on the mean of the contaminant concentrations in soil. If data quality objectives are established and followed, and exposure units are chosen to minimize variability in the data, then using the 95% UCL will rarely pose a problem. There is a great deal of uncertainty associated with substituting the maximum value for the 95% UCL. If the maximum value is less than the 95% UCL, it typically means that variability is high and/or data quality is poor. If the maximum value is greater than the 95% UCL, and there is a weight of evidence suggesting that the maximum value is truly a conservative value, ADEC will consider it as a substitute for the UCL. Weight of evidence may include extensive field sampling or extensive documentation of site history. In general, judgmental samples constitute poor data and are not necessarily appropriate for the statistical methods and assumptions employed in a risk assessment.

The distribution of the data set can be determined and the 95% UCL calculated using EPA's ProUCL 5.0 software (USEPA, 2013b). Alternative statistical methods for calculating the 95% UCL will be considered on a project-specific basis and must be approved by ADEC prior to their use.

The maximum detected concentration in groundwater shall be used as the EPC for the assessment of risk posed due to exposure to groundwater (i.e., ingestion, dermal contact, inhalation of volatiles from water). Considering the dynamic nature of groundwater, it is not deemed appropriate to average concentrations over an aquifer. This is recognized in 18 AAC 75.345(e) regarding the point of compliance where groundwater cleanup levels must be met throughout the aquifer. Using the maximum detected concentration provides a conservative approach to assess risks from this pathway, since it assumes the individual well is utilized as a residential drinking water source. This is also consistent with ADEC's compliance determination in 18 AAC 75.380(c)(2), requiring the use of the maximum concentration in groundwater.

Handling of Non-Detects

In cases where measurement data are described as non-detects (NDs), the concentration of the chemical is unknown; although it lies somewhere between zero and the detection limit. Data that includes both detected and non-detected results are called censored data in the statistical literature. There are a variety of ways (e.g., Kaplan Meyer (KM) method, bootstrap methods) to evaluate data that includes values below the detection limit. Some of these parametric and nonparametric methods are available in ProUCL 5.0. ADEC generally recommends the use of the ProUCL 5.0 recommended method of evaluating NDs. However, there are no general procedures that are applicable in all cases and consultation with ADEC is recommended.

Data reduction and field duplicate samples

ADEC regulates based on the maximum result or statistically valid 95% upper confidence limit (UCL) per 18 AAC 75.380(c)(1). Therefore, ADEC requires that the most conservative detectable sample result of the primary and duplicate results be used for management decision-making purposes.

In the event that more than one contaminant result is reported due to multiple analyses by a single method, the highest detected value will be used. If more than one result is reported from alternate analytical method(s) for a single contaminant, the highest detected value **OR** the result from the confirmatory method shall be used. This determination is made on a compound-specific basis. Any method-specific reporting requirements must also be adhered to. If results are reported as ND by multiple analyses or methods, the undetected result with the lowest detection limit (DL) may be selected for reporting.

Fate and Transport Models

Fate and transport models and exposure models may be used to estimate exposure concentrations in media that have not been sampled. Use of all proposed models must be discussed in the HHRA work plan and must be approved by ADEC. Models must be chosen on a site-specific basis. All model assumptions/inputs must be provided in the risk assessment work plan and approved by ADEC prior to use of the model. The following criteria must be considered when selecting models

for use in the HHRA:

- The model must provide conservative predictions.
- The model must be technically sound and legally defensible.
- The model is within the public domain.
- Model information and reviews are published in reputable technical journals.
- The model has received adequate peer review.

For general guidance on the application of models, consult ADEC's *Fate and Transport Modeling Guidance* (ADEC, 2017).

3.3 Toxicity Assessment

The toxicity assessment identifies the potential adverse effects associated with COPCs and estimates, using numerical toxicity values; the likelihood that these adverse effects will occur based on the extent of the exposure. The preparation of a toxicity assessment relies primarily on existing toxicity information and does not usually involve development of toxicity values or dose-response relationships.

3.3.1 Toxicity Hierarchy

For all exposure routes, there are generally two approaches for deriving toxicity values. One involves the derivation of a chronic reference value (e.g., RfC or RfD_o), while the other involves derivation of a predictive cancer risk estimate (e.g., SF_o or IUR). USEPA uses a weight of evidence approach to classify the likelihood that the agent in question is a human carcinogen. The chronic reference value is an estimate of a daily exposure level for humans, including sensitive subpopulations that are likely to be without an appreciable risk of deleterious effects during a lifetime.

Consistent with the USEPA directive (USEPA, 2003c), ADEC relies upon the following hierarchy of sources for toxicity values:

Tier 1: USEPA's Integrated Risk Information System (IRIS).

Tier 2: USEPA's Provisional Peer Reviewed Toxicity Values (PPRTVs).

Tier 3: Other resources as needed and as approved by ADEC on a case-by-case basis. Other resources that may be considered are CalEPA, ATSDR MRLs, or USEPA's HEAST values.

In selecting values using Tier 3 sources, priority shall be given to sources of information that meet the criteria described below. These criteria are consistent with The Environmental Council of the States and EPA white paper on Tier 3 toxicity values. (ECOS, 2007 and USEPA, 2013a).

1. Transparent assessment that clearly provides the information used and how it was used.
2. Externally and independently peer reviewed, where reviewers and affiliations are identified.
3. Established and publicly available methodology with the current best scientific information and practices.

4. Consideration of higher quality studies used.
5. Publicly available or accessible.

Consultation with ADEC is recommended when using toxicity values other than those from IRIS or PPRTVs to ensure appropriate values are used. The USEPA derived toxicity values may not be available for all substances and all routes of exposure. Toxicity values may be developed by, or in consultation with, the Superfund Technical Support Center at the Environmental Criteria and Assessment Office (ECAO) with the coordination of ADEC risk assessment staff. Important chemicals with an insufficient toxicity database may be referred to bodies such as the EPA or the National Toxicology Program for consideration for future testing.

Neither IRIS nor the PPRTV databases contain radionuclide slope factors. USEPA's Office of Radiation and Indoor Air (ORIA) obtains peer review on the radionuclide slope factors contained in the Radionuclide Table of HEAST. In consultation with USEPA, ADEC shall follow this protocol for radionuclides.

3.3.2 Exposure Route Toxicity Values

Toxicity values are provided for the three main routes of exposure: ingestion, inhalation, and dermal exposure.

Toxicity values for the ingestion pathway are usually provided as the oral slope factor (SF_o) for carcinogens, and as the oral reference dose (RfD_o) for non-carcinogens. Chronic oral reference doses and ATSDR chronic oral MRLs are expressed in units of (mg/kg-day). Oral slope factors are toxicity values for evaluating the probability of an individual developing cancer from oral exposure to contaminant levels over a lifetime. Oral slope factors are expressed in units of $(mg/kg\text{-}day)^{-1}$. This conversion is shown below:

$$SF_o(mg/kg-day)^{-1} = \frac{\text{Water Unit Risk } (\mu g/L)^{-1} \times \text{ Body Weight } (kg) \times 10^3\ \mu g/mg}{\text{Water Consumption } (L/day)}$$

For the inhalation route, a reference concentration (RfC) is an estimate of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. USEPA chronic inhalation reference concentrations are expressed in units of (mg/m^3). The inhalation unit risk factor (IUR) is defined as the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air. Inhalation unit risk toxicity values are expressed in units of $(mg/m^3)^{-1}$. Additional guidance regarding inhalation risk can be consulted from Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment (USEPA, 2009)).

USEPA has not developed SFs or RfDs for dermal exposure to all chemicals, but has provided a method for extrapolating dermal toxicity values from oral toxicity values (USEPA, 2004). This route-to-route extrapolation has a scientific basis; once a chemical is absorbed, its distribution, metabolism, and elimination patterns are usually similar, regardless of exposure route. However, dermal toxicity values typically are based on absorbed dose, whereas oral exposures usually are expressed in terms of administered dose. Consequently, if adequate data regarding the gastrointestinal absorption of a COPC are available, then the dermal toxicity values may be derived

by applying a gastrointestinal absorbance factor (ABS_{GI}), the percentage of contaminant absorbed in the gastrointestinal tract, to the oral toxicity value. For chemicals lacking a gastrointestinal absorbance value, the ABS_{GI} is assumed to be 100% and the RfD_o or SF_o will be used to estimate toxicity via dermal absorption. The equations used to calculate the dermal slope factor and dermal reference dose from the ingestion toxicity values are shown below:

$$SF_d(mg/kg-day)^{-1} = \frac{SF_o\,(mg/kg-day)^{-1}}{ABS_{GI}}$$

$$RfD_d(mg/kg-day) = RfD_o\,(mg/kg-day) \times ABS_{GI}$$

3.3.3 Toxicity Equivalence Factors for Dioxins, Furans, and PCBs and Relative Potency Factors for cPAHs

Some chemicals are members of the same family and exhibit similar toxicological properties; however, they differ in the degree of toxicity. Therefore, a toxicity equivalence factor (TEF) must first be applied to adjust the measured concentrations to a toxicity equivalent concentration. ADEC recommends the use of the World Health Organization 2005 values for dioxin-like toxicity equivalency factors for Dioxins, Furans, and PCBs (USEPA, 2010; van den Berg *et al.,* 2006).

EPA's current approach to assessing cancer risk for polycyclic aromatic hydrocarbon (PAH) mixtures uses the relative potency factor (RPF) approach, which estimates the cancer risk of individual PAHs relative to benzo[a]pyrene (BaP). When assessing the risks posed by carcinogenic polycyclic aromatic hydrocarbons (cPAHs), the responsible party shall use the RPFs presented in *Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons* (USEPA, 1993a). The RPFs should be applied to either the concentrations of cPAHs found in environmental samples or to adjust the available toxicity values for the cPAHs, but not to both. If the adjusted toxicity values are used, the user will need to sum the risks from all cPAHs as part of the risk assessment to derive a total risk from all cPAHs. A total risk from all cPAHs is what is derived when the RPFs are applied to the environmental concentrations of cPAHs and not to the toxicity values.

3.3.4 Special considerations

Some contaminants such as cadmium and manganese have toxicity values specific to a particular media corresponding to the dosing route used in the toxicity study. Other contaminants such as vanadium and thallium compounds have toxicity values that are based upon ionic forms (vanadium peroxide and thallium sulfate). For other contaminants such as the aminodinitrotoluenes, a surrogate approach is used whereby the oral RfD for 2,4-dinitrotoluene is used as a surrogate for 2-amino-4,6-dinitrotoluene and 4-amino-2,6-dinitrotoluene. In all such cases, these special considerations must be clearly noted in the risk assessment.

3.3.4.1 Lead

If lead is found to be a COPC, site-specific risk models such as the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) and the Adult Lead Model (ALM) must be used to determine lead cleanup levels. In a residential scenario the most sensitive receptor is a child exposed to lead and, therefore, the IEUBK must be used to determine appropriate cleanup levels. In a non-residential setting, such as a commercial or industrial scenario, the most sensitive receptor is the fetus of a worker who develops a body burden as a result of non-residential exposure to lead. The ALM must be used in this instance.

Resources to Assess Exposure to Lead

- ☐ *Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children* (USEPA, 1994a) and IEUBK model (USEPA, 2009a)
- ☐ *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil* (USEPA, 2003d) and ALM Spreadsheet (USEPA, 2003a)

The IEUBK attempts to predict blood-lead (PbB) concentrations for children exposed to lead in their environment. The model allows the user to input relevant absorption parameters (e.g., the fraction of lead absorbed from water) as well as intake and exposure rates. Using these inputs, the IEUBK model rapidly calculates and recalculates a complex set of equations to estimate the potential concentration of lead in the blood for a hypothetical child (6 months to 7 years of age). Measured lead concentration is not only an indication of exposure, but also a widely used index for discerning future health problems.

USEPA has determined that childhood PbB concentrations at or above 10 micrograms of lead per deciliter of blood (µg Pb/dL) present risks to children's health with the IEUBK model. Accordingly, USEPA management actions seek to limit the risk that children will have lead concentrations above 10 µg Pb/dL. The IEUBK model calculates the probability that children's PbB concentrations will exceed 10 µg Pb/dL. By varying the data entered into the model, the user can evaluate how changes in environmental conditions may affect PbB levels in potentially exposed children. The IEUBK could be used to assess exposure to lead in a residential setting and to develop alternative cleanup levels. However, it must be noted that ADEC will **not** approve an alternative residential lead cleanup level greater than the default residential cleanup level of 400 mg/kg in soil.

The ALM must be used to assess exposure to lead in a non-residential setting. The ALM assesses non-residential adult risks utilizing a methodology that relates soil lead intake to blood lead concentrations in women of childbearing age. The ALM estimates the soil lead concentration at which the probability of blood lead concentrations exceeding 10 µg Pb/dL in fetuses of women exposed to environmental lead is no greater than 5%. By varying data entered into the model such as environmental conditions (i.e., concentration of lead in soil, dust, food, etc.) or exposure parameters, alternative cleanup levels for lead can be developed.

The default bioavailability parameter incorporated in the IEUBK Model for Children and the default bioavailability parameter incorporated in the *Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in*

Soil (USEPA, 2003d), or the most current version must be used. If alternate bioavailability values are proposed (based either on *in vivo* studies, blood lead studies, or other studies) for use in the IEUBK model or the Adult model, the proposed values must be submitted to ADEC and the Technical Review Workgroup (TRW) for Lead for review. The proposed values must be compared to current guidance regarding use of the IEUBK, blood lead studies, and other studies.

Note that neither the ALM nor the IEUBK are recommended for acute exposure scenarios (i.e., less than 1 day per week for 90 days in duration). Consideration of the use of alternative models must be done in consultation with ADEC risk assessment staff.

Note that given that lead risks are calculated separately from other contaminants, the cumulative risk estimate calculated for a site with lead and other contaminants (including naturally occurring background compounds) may underestimate actual risks. This important issue must be acknowledged and included as a source of uncertainty. Critical effects for each contaminant and any potential additive, synergistic, or antagonistic effects must be carefully considered. Several studies have shown that the effects of other metals with lead are greater than additive (i.e., arsenic-lead and cadmium-lead). Although no specific data exist to quantify the joint risks of the mixtures, endpoints of potential concern for the mixtures include critical effects of the individual metals as well as the common targets of toxicity that might become significant due to additivity (considering secondary effects) or certain interactions.

3.3.4.2 Risk from Bulk Hydrocarbons

Cumulative risks from summation of petroleum fractions must be calculated and presented in the HHRA; however, they are not included in the cumulative risk calculation with other chemicals in the tables. Individual risks from each petroleum fuel fraction (i.e., total GRO, DRO, and RRO) must be calculated and presented in the HHRA as follows:

GRO aliphatic risk + GRO aromatic risk = total GRO risk
DRO aliphatic risk + DRO aromatic risk = total DRO risk
RRO aliphatic risk + RRO aromatic risk = total RRO risk

Each petroleum fraction is a mixture of many different chemicals. As stated in ADEC's *Procedures for Calculating Cumulative Risk* (ADEC, 2018b), the Total Petroleum Hydrocarbon Criteria Working Group identified indicator contaminants within petroleum that can be evaluated individually. Toxicological information is available for each indicator compound and must be used to calculate risks due to petroleum. Differences in calculated risk from bulk hydrocarbons versus petroleum constituents must be discussed in the uncertainty section.

3.3.5 Types of Exposures: Chronic, Subchronic, and Acute

An HHRA must consider carcinogenic and non-carcinogenic effects of chronic and subchronic exposure for appropriate scenarios. Chronic exposures are repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans. For a residential scenario, a 6-year old child with chronic toxicity values should be assessed separately due to the inherent difference in exposure from that of an adult. Subchronic exposures are repeated exposure by the oral, dermal, or inhalation route for

more than 30 days up to approximately 10% of the life span in humans. For subchronic effects, USEPA-developed subchronic toxicity values must be used, if available. Subchronic toxicity values may not be derived from chronic toxicity values using additional uncertainty factors based on the study used to develop the chronic toxicity value. Use of subchronic toxicity values must be approved by the ADEC risk assessor prior to use in the risk assessment.

Acute exposures (less than two weeks) may be of concern in hot spot areas and must be addressed immediately and in conjunction with the appropriate state or federal health agencies.

3.3.6 Toxicity Profiles

The final HHRA must provide toxicity information for each COPC. A brief discussion of the toxicity of the COPCs in the text or a short toxicity profile in the appendix will suffice. At a minimum, toxicity information must be discussed for COPCs that contribute significantly to the overall risk at the site.

3.4 Risk Characterization

The information from the exposure assessment and the toxicity assessment is integrated to form the basis for the characterization of human health risks. The risk characterization presents qualitative and quantitative descriptions of risks. The numerical values in the risk characterization must be accompanied by the interpretive discussion qualifying the risks. The risk characterization serves as the bridge between risk assessment and risk management.

The risk characterization must include the following elements in the final discussion:

- Confidence that key site-related contaminants have been identified and their nature and extent fully characterized.
- Description of known or predicted health risks.
- Confidence in the toxicity information supporting the risk estimates.
- Confidence in the exposure assessment estimates.
- Magnitude of the cancer and noncancer risks relative to the site-remediation goals.
- Major factors driving the risks including contaminants, pathways, and scenarios.

The risk characterization must be conducted in a manner that is consistent with the principles of transparency, clarity, consistency, and reasonableness (TCCR) outlined in USEPA's Risk Characterization Policy (EPA, 2000g).

3.4.1 Carcinogenic Risk

For carcinogens, risks are defined as the likelihood of an individual developing cancer over a lifetime as a result of exposure to the chemical. Carcinogenic risk is defined as the incremental risk of cancer due to exposure from site-related contaminants, averaged over a lifetime and calculated by multiplying intake of contaminants by the cancer slope factor. This will represent risk-per-unit dose.

$$Carcinogenic\ Risk_{(oral)} = Intake \times Slope\ Factor$$

$$Carcinogenic\ Risk_{(inhalation)} = Exposure\ Concentration\ X\ Inhalation\ Unit\ Risk$$

Incremental cancer risks must be estimated separately for each exposure scenario and for each subpopulation. The individual chemical cancer risk is rounded and presented to two significant figures and the incremental lifetime cancer risk is presented using one significant figure. USEPA's *Guidelines for Carcinogen Risk Assessment* (or *Cancer Guidelines*) (2005a) emphasizes using mode of action (MOA) information in interpreting and quantifying the potential cancer risk to humans. USEPA's *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (or *Supplemental Guidance*) (2005c) also relies on assessing the MOA. In particular, the *Supplemental Guidance* advises that age-dependent adjustment factors (ADAFs) be used with the cancer slope factors and age-specific estimates of exposure in the development of risk estimates, if the weight of evidence (WOE) supports a mutagenic MOA for carcinogenicity. This default approach is used only when appropriate chemical-specific data are not available on susceptibility from early-life exposures. Cancer slope factors (SFs) or unit risk values are used to estimate upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen. Understanding of mode of action can be a key to identifying processes that may cause chemical exposures to differentially affect a particular population segment or lifestage. Some modes of action are anticipated to be mutagenic and are assessed with a linear approach.

Evaluating Risks from Childhood Exposures

The National Research Council (NRC) recommended that USEPA must assess risks to infants and children whenever it appears that their risks might be greater than those of adults (NRC, 1994). Executive Order 13045 (1997) requires that each Federal Agency shall make it a high priority to identify and assess environmental health and safety risks that may disproportionately affect children, and shall ensure that their policies, programs, and standards address disproportionate risks that result from environmental health risks or safety risks. In assessing risks to children, USEPA considers both effects manifest during childhood and early-life exposures that can contribute to effects at any time later in life. These cancer guidelines view childhood as a sequence of lifestages rather than viewing children as a subpopulation; the distinction being that a subpopulation refers to a portion of the population, whereas a lifestage is inclusive of the entire population. Exposures that are of concern extend from conception through adolescence and also include pre-conception exposures of both parents. The USEPA's *Guidelines for Carcinogen Risk Assessment* (USEPA, 2005a) uses the term childhood in this more inclusive sense. At this time, there is some evidence of higher cancer risks following early- life exposure. To evaluate risks from early-life exposure, these cancer guidelines emphasize the role of toxicokinetic information to estimate levels of the active agent in children and toxicodynamic information to identify whether any key events of the mode of action are of increased concern early in life. In the dose-response assessment, the potential for

susceptibility during childhood warrants explicit consideration in each assessment. The USEPA's cancer guidelines encourage developing separate risk estimates for children according to a tiered approach that considers what pertinent data are available. Childhood may be a susceptible period; moreover, exposures during childhood generally are not equivalent to exposures at other times and may be treated differently from exposures occurring later in life. In addition, adjustment of unit risk estimates may be warranted when used to estimate risks from childhood exposure. USEPA developed, in conjunction with the 2005 cancer guidelines, the *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (or *Supplemental Guidance*) (2005c). The *Supplemental Guidance* addresses a number of issues pertaining to cancer risks associated with early-life exposures generally, but provides specific guidance on procedures for adjusting cancer potency estimates only for carcinogens acting through a mutagenic mode of action. The *Supplemental Guidance* recommends, for such chemicals when no chemical-specific data exist, a default approach using estimates from chronic studies (i.e., cancer slope factors) with appropriate modifications to address the potential for differential risk of early-lifestage exposure.

3.4.2 Noncarcinogenic Risk

For non-carcinogens, the HQ is calculated as the intake or exposure concentration of the compound divided by the reference value. Hazard indices (HIs), the sum of multiple HQs, must be calculated separately for each scenario and for each exposed population. The HQ must be presented using two significant figures.

$$Hazard\ Quotient_{(oral)} = \frac{Intake}{RfD}$$

$$Hazard\ Quotient_{(inhalation)} = \frac{Exposure\ Concentration}{RfC}$$

Non-carcinogenic compounds affect different target organs or systems by different mechanisms of toxicity. To accurately assess the cumulative risk of possible effects for non-carcinogenic compounds, the HI can be further segregated by target organ or system endpoint and mechanism of toxicity consistent with USEPA's *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A) – Interim Final* (USEPA, 1989a), *Guidelines for the Health Risk Assessment of Chemical Mixtures* (USEPA, 1986), and *Supplemental Guidance for Conducting Health Risk Assessment of Chemical Mixtures* (USEPA, 2000f). Since the mechanism of toxicity is not well understood for many compounds, the department will evaluate segregation of the HI by target organ or system endpoint." The HI must be presented using one significant figure.

3.4.3 Cumulative Risk

Initially, risks and HQs are calculated for individual COPCs; however, at most sites, there are multiple COPCs. To assess the overall potential for cancer and non-cancer effects posed by exposure to multiple chemicals, risk from multiple COPCs and multiple exposure pathways must

be summed. The process for calculating cumulative risk is provided in ADEC's *Procedures for Calculating Cumulative Risk* (ADEC, 2018b), adopted by reference in 18 AAC 75.325(g) and should incorporate the most updated toxicity values from the hierarchy discussed in section 3.3.1 at the time of the risk assessment. Contaminants are generally divided into two basic groups; those that have a carcinogenic effect and those that have a non-carcinogenic effect. Cumulative carcinogenic risk and non-carcinogenic hazard index are calculated separately. However, some compounds can cause both effects and therefore must be included in both cumulative risk calculations.

3.4.4 Development of Alternative Cleanup Levels

An HHRA and Ecological Risk Assessment (ERA) provide details about what COPCs in each media contribute to risk. Ultimately the goal of many HHRAs and ERAs is to derive ACLs.

Risk-based equations were derived in order to reflect the potential risk from exposure to a chemical, given a specific pathway, medium, and the reasonable maximum exposure expected to occur under current and future site conditions, including land use. ACLs can be calculated by setting the total carcinogenic risk or HI at the standard approved by ADEC and solving for the concentration term for each chemical in a particular medium. ADEC requires that the risk and HIs at a site do not exceed the standards listed below:

- Target cancer risk level at or below 1 in 100,000.
- HI of 1.

The ACL should also be protective of the potential for the COPC to migrate to other media and cause risk to exceed the required standard. Although risks from groundwater ingestion must be considered for the commercial/industrial (or other) exposure scenarios, it is not appropriate to calculate alternative cleanup levels for groundwater based upon such scenarios. Groundwater cleanup levels are to be considered ARARs as determined under 18 AAC 75.345. Even if a site is located in an industrial area, the groundwater underlying a site in an industrial area may be used as a drinking water source for residents several miles away due to complex geological interconnections. As noted in **RAGS B Exhibit 2-1** footnote **d** in regard to drinking water at commercial/industrial sites: "*Because the NCP encourages protection of ground water to maximize its beneficial use, risk-based PRGs generally must be based on residential exposures once groundwater is determined to be suitable for drinking water. Similarly, when surface water will be used for drinking water, general standards (e.g., ARARs) are to be achieved that define levels protective for the population at large, not simply worker populations. Residential exposure scenarios must guide risk-based PRG development for ingestion and other uses of potable water.*"

Please also note that ADEC *18 AAC 70 Water Quality Standards* are to be considered ARARs for surface water (and groundwater in connection with surface water per 18 AAC 75.345 (g) regardless of risk calculated for this media.

3.4.5 Uncertainty Assessment

The risks presented in an HHRA are conditional estimates based on multiple assumptions about exposures, toxicity, etc. Each assumption is associated with some degree of uncertainty. These uncertainties may contribute to an overestimation or underestimation of the risks at the site.

Therefore, to place the risk estimates in their proper perspective, it is important that, at a minimum, a qualitative discussion of uncertainty be included in all HHRAs performed for ADEC.

Sources of uncertainty include natural variability, measurement error, sampling error, human error, extrapolation mandated by an incomplete knowledge base and/or incorrect assumptions, and oversimplification. Each contributor to the uncertainty of a value or decision must be documented in the HHRA at the point where the data are introduced and all uncertainty associated with data presented in the risk characterization must be presented in the uncertainty section. All uncertainty factors must be identified and discussed quantitatively and or qualitatively with respect to their overall impact on the HHRA. Specific uncertainty factors to be considered in an HHRA are included below (see EPA 1989a, Sections 6.8, 7.6, and 8.4 for details).

3.4.6 Uncertainty in Data Evaluation

Several topics associated with data used in the selection of compounds of concern need to be discussed in the uncertainty section of the HHRA. These include the data collection, data evaluation, and data reduction techniques. Furthermore, any other factors that are associated with the data and which can influence selection of compounds of concerns for the HHRA must be also be discussed. These include data gaps, detection limits, and other relevant issues.

3.4.7 Uncertainty in the Exposure Assessment

Multiple assumptions in the exposure assessment can significantly impact the HHRA results and introduce bias. Consider the level of uncertainty when using default and site-specific exposure factors to calculate RMEs for receptors and exposure pathways that are both currently occurring and that could reasonably occur in the future. In addition, there is a level of uncertainty with estimating the exposure point concentration from measurements (rather than if it is a calculated UCL or maximum detection) or from results of modeling.

3.4.8 Uncertainty in the Toxicity Assessment

The weight of evidence and the confidence in the database supporting non-carcinogenic effects must be identified and included. It is also important to identify uncertainty as a result of not evaluating substances in the HHRA because of inadequate toxicity information. The possible consequences of excluding substances and impacts to the overall estimate of risk for a site must also be evaluated. Page 8-24 of the USEPA guidance (USEPA, 1989a) provides a checklist of the uncertainties that apply to most toxicity assessments.

4.0 ECOLOGICAL RISK ASSESSMENT

Ecological risk assessment (ERA) is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. Because every site is unique, the scope and complexity of an ERA will vary from site to site. Subsection 4.1 presents a general overview of the ERA process in Alaska. Specific recommendations for implementing problem formulation, evaluating ecological exposure and effects, characterizing risk, and evaluating uncertainty are presented in subsections 4.2 to 4.5, respectively. Other useful resources include: *Guidelines for Ecological Risk Assessment* (USEPA, 1998); *EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund* (USEPA, 1997b). ADEC resources include: *Ecoscoping Guidance* (ADEC, 2014); *User's Guide for Selection and Application of Default Assessment Endpoints and Indicator Species in Alaskan Ecoregions* (ADEC, 1999a); *Technical Background Document for Selection and Application of Default Assessment Endpoints and Indicator Species in Alaskan Ecoregions with figures and tables updated in September of 2008* (ADEC, 1999b).

4.1 ERA Process in Alaska

ADEC's *Ecoscoping Guidance* (ADEC, 2014) helps delineate information to gather at every site and how to determine if further assessment is required at a particular site. If a risk assessment is required, the information gathered as part of the scoping process will aid in the risk assessment problem formulation.

The ERA process is iterative, with results of early steps used to focus subsequent efforts on important chemicals, pathways, and issues. Each step in the process must result in a decision point where one of the following three decisions is made:

1. There are adequate data to conclude that ecological risks are negligible and there is no need for remediation based on ecological risk.
2. The information is not adequate to make a decision at this point and the ERA process must continue.
3. The information indicates potential for adverse ecological effects, and either a more thorough assessment or remediation based on ecological risk is warranted.

Although risk assessments often include quantitative risk estimates, quantitation of risks is not always possible. In such cases, potential risks and associated uncertainties must be qualitatively described (USEPA, 1998).

The four main steps in ADEC's ERA process are described below. The overall process is summarized in the flowchart shown as Figure 2 (see Appendix B). As shown in Figure 2, ADEC requests that a scoping meeting be conducted at the onset of process. Subjects to be discussed at the scoping meeting are detailed in the *Scoping Meeting Checklist/Sample Agenda* provided in Appendix A.

4.1.1 Ecological Scoping Evaluation - Step 1

ADEC has developed a scoping document (ADEC, 2014) designed to quickly eliminate sites that are unlikely to pose a risk to the environment. Such sites exit the ERA process without further evaluation. The scoping evaluation cannot be performed at a site unless there is information about the following: contaminant toxicity, quantity and potential for bioaccumulation, quality and extent of habitat, presence of receptors and a record of observed direct impacts from contamination. Site maps and other descriptive information are also necessary.

4.1.2 Preliminary Screening Evaluation - Step 2

If ecological receptors are likely to be exposed to site-related contaminants, chemical concentrations in environmental media that are identified during the scoping evaluation are then compared to conservative screening benchmarks as part of the preliminary screening evaluation within the scoping document. Acceptable conservative screening values are provided in the Risk Assessment Information System (available at: http://rais.ornl.gov/). These values generally represent the lowest benchmark available for a given media. If site concentrations in media exceed these conservative benchmarks, but benchmarks exist that may be more appropriate to the receptors at the site, a screening level risk assessment may be performed. In this instance, further detail on the site and rationale for selection of specific benchmarks must be provided. The screening level risk assessment is described in the next section.

The scoping results must be submitted to ADEC for review in additional to preliminary screening when likely exposure to site-related contamination is determined. After reviewing the results, ADEC will determine whether further ERA work is warranted, or whether ecological risks are negligible and the site can exit the ERA process.

4.1.3 Screening-Level ERA - Step 3

Step 3 in the Alaska ERA process is analogous to the screening-level ERA in federal guidance (USEPA, 1997a). This step incorporates the three basic elements of risk assessment—problem formulation, analysis of exposure and effects, and risk characterization—in an abbreviated form. The three main elements of the risk assessment process are related, as shown in Figure 3 (see Appendix B). An uncertainty evaluation also must be included in the screening-level ERA. Subsections 4.2 to 4.5 provide recommendations for implementing these activities. It must be noted that Step 3 includes several activities that are not included in the preliminary screening evaluation conducted in Step 2. Most importantly, Step 3 includes a screening-level problem formulation (in which assessment endpoints and measures of effect are described), presents screening-level HQs for wildlife receptors, and identifies data gaps. ADEC review and approval of the screening-level ERA is required (see Figure 2).

4.1.4 Baseline ERA - Step 4

A baseline ERA is required when sites are complex or when scoping and screening has indicated a potential ecological risk. ADEC requires that an ERA work plan (WP) and a sampling and analysis plan (SAP) be developed prior to development of the baseline ERA. The ERA work plan must summarize the screening-level ERA, list data gaps, describe additional studies needed to fill the data gaps, and describe methods to be used to quantify exposure and characterize risk for all

receptor groups being evaluated. The methodology recommended for use in developing the BERA is described in the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final* (USEPA, 1997a). Additional guidance for ecological risk assessment can be found in the following USEPA publications: *Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual* (USEPA, 1989b), and the *Guidelines for Ecological Risk Assessment* (USEPA, 1998). Subsection 2.2 provides additional recommendations for the ERA work plan. When developing the ecological investigation, WP and SAP content should be similar to that described by USEPA (1988a and 1989b). After ADEC approval of the work plan, the baseline ERA must be completed and submitted to ADEC for review (see Figure 2). The baseline ERA includes the same basic elements found in the screening-level ERA—problem formulation, analysis of exposure and effects, and risk characterization—in a more developed form.

The information presented in subsections 4.2 to 4.5 is most applicable to Steps 3 and 4 in ADEC's overall ERA process. These two steps will result in ERA reports with major sections for problem formulation, ecological exposure and effects, risk characterization, and uncertainty analysis. Nonetheless, some material in the following subsections also is relevant to Steps 1 and 2, especially the material relevant to CSM development, which begins in these early steps.

4.2 Problem Formulation

The first stage of SLERA is problem formulation. Problem formulation is the process for generating and evaluating preliminary hypotheses about why ecological effects have occurred or may occur from human activities (USEPA, 1998).

4.2.1 Components of Problem Formulation

The fundamental components necessary for problem formulation are:

- Environmental setting and site history.
- Documentation of site visits.
- Contaminants known or suspected to be at the site.
- Information about which receptors are most likely to be present at this site. *The Technical Background Document for Selection and Application of Default Assessment Endpoints and Indicator Species in Alaskan Ecoregions with figures and tables updated in September of 2008* (ADEC, 1999b) would be useful in accomplishing this.
- Contaminant fate and transport evaluation emphasizing site-related chemicals, gradients of contamination, and identification of all potentially affected media.
- Preliminary ecotoxicity evaluation focusing on probable site-specific toxicity mechanisms to species or habitats of concern.
- Preliminary exposure pathway analysis showing the potential for completed pathways to species or habitats of concern. This information goes into the CSM.

Problem formulation activities generate three products:

1. **Conceptual site models** – are developed from site information and knowledge of habitats and life histories of receptors.
2. **Assessment endpoints** – detailed species or communities to protect in order to reach broader management goals.
3. **Measures (previously called *measurement endpoints*)** – are used to evaluate potential effects on the assessment endpoints.

Site management goals and objectives must be identified or developed prior to the selection of assessment endpoints.

4.2.2 Ecological Conceptual Site Models

To develop a CSM for the ecosystem, there must be at least rudimentary knowledge of the environmental setting, the presence of potentially hazardous substances, and physical and biological stressors at the site. For guidance on developing ecological CSMs, see ADEC's *Policy Guidance on Developing Conceptual Site Models* (ADEC, 2017).

4.2.3 Selection of Assessment Endpoints

Assessment endpoints are parts of the ecosystem identified as important to its overall health or to a particular component of the ecosystem that is particularly of value. They explicitly state what function of a community or species is to be protected and how protecting that part of the ecosystem fits in with larger management goals. Assessment endpoints must be specific and clear enough to provide risk assessors and risk managers with sufficient direction and detail for determining measurable outcomes. Measures are selected and evaluated to determine whether the assessment endpoints are being adversely affected (see subsection 4.2.4 for explanation of measures).

Assessment endpoints can be identified at the individual, population, or community level of biological organization. Examples of these levels of assessment endpoints are provided below:

Individual Level	Threatened or Endangered species Changes in top predator activity
Population Level	Survival and reproduction of native Brook trout Survival and reproduction of Eastern Bluebirds Survival and reproduction of meadow voles (prey base)
Community Level	Estuarine communities Wetland plant communities Grassland communities Sensitive habitat communities Sensitive environments

In general, there are two parts to an assessment endpoint: an ecological entity and a characteristic

about the entity that is important to assess. Assessment endpoints must not be management goals or values and they must not be vague.

The three principal criteria used to select ecological values that may be appropriate for assessment endpoints are ecological relevance, susceptibility to known or potential stressors, and relevance to management goals (USEPA, 1998). For species and communities that are not threatened or endangered, usually it is appropriate to protect them at the population or community level. Guidance for selecting assessment endpoints in Alaska can be found in *User's Guide for Selection and Application of Default Assessment Endpoints and Indicator Species in Alaskan Ecoregions* (ADEC, 1999). Additional information on establishing assessment endpoints can be found in *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment* (USEPA, 2003b).

ADEC requires that threatened and endangered species be identified in the ecological risk assessment. Where applicable, threatened and endangered species shall be used as assessment endpoints in accordance with state and federal laws. An indicator species from the same trophic level must be selected as a surrogate to assess ecological risk to the endangered species.

Alaska sensitive environments are defined in 18 AAC 75.610, 18 AAC 75.620, 18 AAC 75.630, and 18 AAC 75.990(35). Examples of state and federal sensitive environments are provided in Table 2.

Table 2 Sensitive Environments

State		Federal
State wildlife refuges		Critical habitat for federal-designated endangered or threatened species
State land designated for wildlife or game management		Marine sanctuaries
State-designated scenic or wild rivers		National parks
State-designated natural areas		Designated federal wilderness areas
State-designated areas for protection or maintenance of aquatic life		Areas identified under the Coastal Zone Management Act
Spawning areas critical for the maintenance of fish or shellfish species within rivers, lakes, or coastal tidal waters		Sensitive areas identified under the national estuary program
Migratory pathways and feeding areas critical for maintenance of anadromous fish species within river reaches or areas in lakes or coastal tidal waters in which the fish spend extended periods		Sensitive areas identified under the near coastal waters program
Terrestrial areas used for breeding by large or dense aggregations of		Critical areas identified under the clean lakes program

State		Federal
animals		
		National monuments
		National seashore recreation areas
		National Lakeshore recreational areas
		National preserves
		National wildlife refuges
		Units of coastal barrier resources systems
		Coastal barriers
		Federal land designated for the protection of natural ecosystems
		Administratively proposed federal wilderness areas
		National river reaches designated as recreational
		Federal-designated scenic or wild rivers

4.2.4 Measures

There are three categories of measures: (1) measures of exposure; (2) measures of effect; and (3) measures of ecosystem and receptor characteristics. Each of these measures is defined below.

Measures of exposure are a measure of dose from co-occurrence of or contact between a stressor and an ecological component. Examples include (1) the amount of a chemical ingested, (2) the amount of a chemical absorbed, and (3) the product of ambient exposure concentration and the duration of exposure.

Measures of effects are measurable changes in an attribute of an assessment endpoint associated with exposure to a stressor (USEPA, 1998). For example, site sediment samples may be used in a toxicity test with laboratory-reared benthic organisms (i.e., a surrogate for benthic fauna at the site) under controlled conditions to evaluate effects on survival, growth, and reproduction (i.e., attributes) from chemicals in sediment. The most appropriate measures of effect depend on the number and types of lines of evidence that are needed to support risk management decisions at the site in question.

Measures of ecosystem and receptor characteristics are measures that influence either the behavior and location of entities selected as the assessment endpoint or the distribution of a stressor and life-history characteristics of the assessment endpoint or its surrogate that may affect exposure or response to the stressor (USEPA, 1998). For example, population characteristics such as density, relative abundance, and reproductive performance can be evaluated to determine the risk from exposure to the chemical(s).

An example of a management goal, an assessment endpoint, and potential measures is outlined below:

Goal: Sustain adequate prey for carnivorous mammals.

Assessment Endpoint

- Potential for adverse effects on the survival and reproduction of the terrestrial mammalian insectivores.

Measures of Effects

- Analysis of adverse health effects to shrews.
- Reproductive success of female shrews.
- Density of shrews in a specified area.
- Species community analysis.

Measures of Ecosystem and Receptor Characteristics

- Quality and extent habitat (e.g., vegetative cover, preferred habitat structure).
- Abundance and distribution of juvenile and adult food sources.
- Presence of burrows and runways in appropriate habitat.
- Environmental conditions (e.g., temperature, rainfall).

Measures of Exposure

- Chemical concentrations in soil and food items.
- Modeled intake of chemicals from soil and food.

Use USEPA's *Guidelines for Ecological Risk Assessment* (USEPA, 1998) and EPA *Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund* (USEPA, 1997b) to assist in establishing measures. If additional data are needed, sampling plans must be designed around the selected measures. Modeling is also acceptable at this point.

4.3 Analysis (Ecological Effects Evaluation)

In the analysis phase, measures of exposure and measures of effect are used to estimate the impacts of contamination in environmental media. This relies on the concept of dose response. Different contaminants are toxic to different species in different amounts. The intake of contaminant can be related to an actual or anticipated effect. For example, if a measure of effect such as reproductive success is chosen, the exposure estimate can be compared to published literature values describing the relationship between the contaminants and reproductive effect.

Some primary methods for evaluating potential adverse effects to ecological receptors are: (1) hazard quotient method; (2) population/community evaluations; (3) toxicity tests; and (4) bioaccumulation and field tissue residue studies. The hazard quotient method is the most commonly utilized method. Site-specific methods are used when the assumptions employed in the screening level and baseline risk assessment are overly conservative or when there is

insufficient published information to perform an adequate analysis. More than one method may be necessary to sufficiently characterize risk to support valid risk management decisions.

4.3.1 Hazard Quotient Method

One method for evaluating ecological risks from environmental contaminants is to predict the potential for adverse effects by comparing estimated levels of exposure of various environmental receptors to appropriate Toxicity Reference Values (TRVs). This section covers the process and alternative approaches.

4.3.1.1 Selection of Indicator Species and Communities

Indicator species and communities must be chosen based on the assessment endpoints, CSMs, food web analysis, and other available site-specific information. Indicator communities typically selected for evaluation at hazardous waste sites include benthic fauna, soil invertebrates, terrestrial plants, and/or wetland plants, depending on the habitats affected by site-related contamination. When assessing wildlife risk, indicator species are species from the same trophic level and feeding guild as assessment endpoints, for which exposure parameters are available. See the 2008 tables and figures referenced in ADEC, 1999b for recommendations on selecting indicator species and communities for Alaskan ecoregions.

4.3.1.2 Selection of Compounds of Potential Ecological Concern

Soil screening benchmarks are available from Oak Ridge National Labs (Efroymson *et al.,* 1997a and 1997b), USEPA (2013a), and published sources such as Alloway (1990). Sediment screening benchmarks are available from NOAA (Buchman, 2008), Oak Ridge National Labs (Jones *et al.,* 1997), and ADEC (2013). Surface water screening benchmarks are available from NOAA (Buchman, 2008), 18 AAC 70, Oak Ridge National Labs (Suter & Tsao, 1996), and Suter (1996). Other screening values from government sources or published literature can be used as needed and appropriate in consultation with ADEC. Measured maximum chemical concentrations in environmental media must be compared with these benchmarks to identify compounds of potential ecological concern (COPECs). As outlined in USEPA's *Framework for Metals Risk Assessment* (2007b), special attention must be paid to metal specific principles such as the influence of environmental chemistry on metal speciation, bioavailability, background levels of metals in the environment, and the ubiquitous presence of metal mixtures (USEPA, 2004b).

For wildlife, screening-level HQs must be calculated as described in USEPA (1997a) using exposure parameters from USEPA (1993b), Sample and Suter (1994), and other reputable sources. Subsection 4.2.1.3.1 provides additional guidance on selecting exposure parameters. ADEC prefers that TRVs be based on no observed adverse effect levels (NOAELs) for initial screening estimates for wildlife to ensure that risk is not underestimated. Subsection 4.3.1.4 discusses the selection and use of TRVs for evaluating wildlife risks.

Bioaccumulative compounds may not be screened out without accounting for their accumulation in the food chain. ADEC defines bioaccumulative compounds as organics with a BCF equal to or greater than 1,000 or log K_{ow} greater than 3.5 and inorganics identified by USEPA (2000a). A list of bioaccumulative compounds commonly found at contaminated sites in Alaska is provided in Table A-1, in Appendix A of *Policy Guidance on Developing Conceptual Site Models* (ADEC, 2017).

After ecological screening benchmarks and TRVs are selected, the screening for COPECs is conducted similarly to human health risk screening, namely:

1. For community-level receptors, compare the maximum concentration to the ecological risk-based benchmark or other appropriate benchmark in tabular format.
2. For wildlife receptors, use the maximum concentration to calculate a screening- level HQ.
3. Eliminate compounds if they do not exceed any of their respective risk-based benchmarks and if the screening-level wildlife HQ is less than 1.
4. Retain compounds that have a potential to bioaccumulate or bioconcentrate.
5. Identify all compounds not eliminated as COPECs and carry these through the remainder of the risk assessment process.
6. All compounds without risk-based benchmarks must be retained for more detailed evaluation in the uncertainty section.

4.3.1.3 Exposure Estimates

The characterization of ecological exposure to chemicals requires the characterization of releases into the environment, the spatial and temporal distribution within the environment, and analysis of the COPECs coming in contact with the ecological receptor. For receptor groups such as plants, soil invertebrates, and benthic life, exposure is defined in terms of contact of a chemical with the outer boundary of the organism and subsequent uptake. For these receptor groups, risk is typically assessed by comparing measured media concentrations to risk-based benchmarks. Exposure via specific pathways is not generally estimated.

For wildlife, exposure is defined in terms of the amount of the compound of concern ingested, inhaled, or absorbed through dermal and internal absorption. It is rare that sufficient data exist to characterize exposure through dermal absorption or through inhalation. Exposure assessment for a wildlife population can be accomplished by incorporating the variability in exposure among individuals within a population, while exposure estimates can be presented as a distribution of exposure in the population or as point estimates to the individual.

4.3.1.3.1 Ecological Exposure Assumptions

When calculating screening-level ecological risks, conservative estimates must be used to estimate exposures in the absence of sound, site-specific information. Conservative assumptions can be replaced with site-specific information for the purpose of calculating ecological risk-based cleanup levels. For a screening-level risk assessment, acceptable ADEC exposure assumptions are listed below:

1. Area use factor = 100%.
2. Bioavailability = 100%.
3. Sensitive life stage = most sensitive life stage.
4. Body weight = minimum body weight.
5. Ingestion rate = maximum ingestion rate.

Alteration of default exposure assumptions may be appropriate in a baseline risk assessment with ADEC approval. Species-specific exposure parameters can be obtained from the *Wildlife Exposure Factors Handbook* (USEPA, 1993b). Other sources of species-specific wildlife exposure

parameters include Sample *et al.* (1996 and 1997) and Sample and Suter (1994).

During a screening-level ERA (Step 3), it may be necessary to model COPC levels in wildlife food. Bioaccumulation factors (BAFs) and/or equations for such modeling can be found in Bechtel Jacobs (1998b) and Baes III *et al.* (1984) for plants, in Bechtel Jacobs (1998a) for benthic invertebrates, in Sample *et al.* (1998b) for earthworms, and in Sample *et al.* (1998a) for small mammals.

4.3.1.4 Selecting and Scaling Toxicity Reference Values

TRVs are analogous to reference doses in human health risk assessment. They are used for wildlife risk characterization and must be based on toxicity studies from the literature. In many cases, uncertainty factors are applied to published toxicity data to make them relevant to indicator species.

In general, the endpoints that ecological risk assessments address for non-endangered species include reproduction, growth, maintenance, and critical developmental processes. Cancer is not usually selected as a chronic ecological endpoint.

Currently, the most extensive compilation of TRVs for wildlife is found in Sample *et al.* (1996). Original papers from the peer-reviewed literature must be consulted for toxicity data for chemicals not included in Sample *et al.* (1996). If a TRV is not available from Sample *et al.* (1996), and suitable data for developing a TRV cannot be found in the peer-reviewed literature, the approaches described in subsection 4.3.1.4.2 must be considered.

Most animal toxicity studies reported in the literature are conducted with small animals (e.g., mice, rats, and chickens) that are adaptable to living in confined spaces. Toxicity data are not available for all wildlife species and chemicals that may be considered in an ERA. Hence, extrapolation of toxic responses observed in test species to wildlife receptors is necessary. Allometric scaling is one commonly used extrapolation approach. Allometric scaling of TRVs must be conducted as described in Sample and Arenal (1999).

4.3.1.4.1 Ecological Uncertainty Factors

For compounds with TRVs, ADEC will accept the uncertainty factors (UFs) listed in Table 3 for appropriate extrapolation to indicator species. The UFs for phylogenic effects need not be applied if allometric scaling of TRVs is conducted as described in subsection 4.3.1.4.

Table 3 Uncertainty Factors

Species-Specific Data		Non-species specific data		
Toxicological data	**UF**	**Effect**	**Difference**	**UF**
Chronic No Observed Effect Level (NOEL)	1	Population Effects	Different Trophic level	2
Chronic NOAEL	1-2		Different Exposure media	2

Species-Specific Data		Non-species specific data		
Toxicological data	**UF**	**Effect**	**Difference**	**UF**
Chronic Lowest Observed Effect Level (LOEL)	5	Biochemical Effects	Toxic intermediate data	4
Subchronic NOEL	5	Phylogenic Effects	Species sensitive to toxic endpoint	½
Subchronic NOAEL	5-10		Different Genus	2
Subchronic LOEL	25		Different Order/Family	4
Subchronic Lowest Observed Adverse Effect Level (LOAEL)	25-50		Different Class	Cannot use data
Acute NOEL	20			
Acute NOAEL	20-40			
Acute LOEL	100			
Acute LOAEL	100-200			
Lethal Dose at 50% (LD50)	250			

For more detailed procedures for deriving TRVs for wildlife receptors, refer to *Performing Ecological Risk Assessments* (Calabrese & Baldwin, 1993). In general, the derivation of TRVs must deal with various uncertainties in the extrapolation of laboratory data to site-specific conditions.

4.3.1.4.2 Alternative Approaches for Developing TRVs

For some contaminants, ecological screening benchmarks and/or TRVs are not available. In such cases, the use of surrogates must be considered. For example, wildlife TRVs for polynuclear aromatic hydrocarbons (PAHs) are limited, but the TRV for benzo(a)pyrene may be used as a surrogate for other PAHs. In addition, quantitative structural activity relationships (QSARs) can be developed. A QSAR is a mathematical relationship between a property of a chemical, either bioconcentration potential or toxicity, and its chemical and/or physical characteristics (Walker 2004). The ecological criteria databases must be used to determine bioconcentration and toxicity data needed to establish a mathematical relationship between the defined property and the descriptor (Hickey *et al.*, 1993). The QSAR can then be used to predict the bioconcentration or toxicity potential of untested chemicals based on their chemical and/or physical characteristics. QSARs may be developed by, or in consultation with, USEPA. However, ADEC risk assessment staff must be consulted before contacting USEPA because similar derivations may be readily available from other risk assessments conducted in Alaska.

4.3.2 Ecological Field Studies

A well-conducted field study can provide a valuable link between site contaminants and potential ecological effects (USEPA, 1997a). The field study will help determine the conditions of organisms at the site. Several endpoints are considered evidence of adverse toxic effects,

including:

- Reduction in species population.
- Absence of species known to inhabit the area.
- Presence of plant or animal species associated with stressed habitats.
- Changes in community balance or trophic structure.
- Frequency of lesions, tumors or other pathological conditions in individuals.

Field studies must be designed and conducted by experienced wildlife biologists and be based on published methodology. USEPA (1999) describes field assessment methods for fish, benthic invertebrates, and periphyton in wadeable streams and rivers. USEPA (1991a) describes field assessment methods for terrestrial plants, vertebrates, and invertebrates at hazardous waste sites. Lastly, a good example of the use of field studies as part of an ERA can be found in Menzie *et al.* (1992).

4.3.3 Toxicity Tests

The bioavailability and toxicity of site contaminants can be tested with toxicity tests or bioassays. As with other methods, it is critical that the media tested are in exposure pathways relevant to the assessment endpoint. Testing methods are available for evaluating the toxicity of chemicals in sediment, surface water, and soil. Standardized test methods have been developed for freshwater fish and plankton (USEPA, 2002e), freshwater benthic invertebrates (USEPA, 2000e), marine and estuarine fish and plankton (USEPA, 2002f), and marine and estuarine benthic invertebrates (USEPA, 2001a). Some aquatic toxicity tests were developed for the regulation of aqueous discharges to surface waters. These tests are useful, but one must consider the original purpose of the test (USEPA, 1997a). Standardized tests also are available for terrestrial plants and soil invertebrates (USEPA, 1988b). For additional information on using toxicity tests in risk assessments, please see USEPA (1994a, 1994b, and 1997a).

4.3.4 Bioaccumulation and Field Tissue Residue Studies

Field tissue residue studies may be done in cases where there is potential to overestimate risk by using conservative BAFs from the literature. Although ADEC may consider such studies for estimating site-specific BAFs, they are not required or even recommended. The biota samples taken must be in the exposure pathway of the assessment endpoint and not the endpoint itself, as toxicity data are rarely available to determine effects from tissue concentrations. Co-located samples of contaminated media must be taken with biota samples. Organisms that are sessile or have limited mobility (i.e., plants, mussels, fish fry, and small mammals) likely represent the site better than animals with a large home range, provided they are a key element in the food chain. It may also be important to consider the season that samples are taken. Sample gender, size, and age must be recorded. Methods for assessing bioaccumulation in aquatic environments can be found in USEPA (2000b and 2000e). It is extremely difficult to obtain sufficient samples to perform a valid background determination in the face of the inevitable high variability typically encountered when sampling biota. For this reason, biota samples must not be taken with the intention of eliminating compounds from the COPC list.

In Alaska, field residue studies are often performed for biota that are subsistence food items; all of the above guidelines have application to such studies, even though the endpoint is different. The most critical issue is that the biota samples taken represent what predators are eating. It is also worth noting that for an ecological risk assessment, whole body contaminant load may be the appropriate determination, whereas for subsistence foods, it is often more appropriate to analyze the tissues and/or organs that are frequently consumed.

4.4 Risk Characterization

Risk characterization must answer the following basic question:

> Are ecological receptors at the site expected to be exposed to levels of contaminants that could harm a community or population important to the functioning of the ecosystem, or to particular valued species within that ecosystem, now or in the future?

Risk estimates must integrate exposure and toxicity information in a way that supplies a measurement of adverse risks. Such a measurement may be a qualitative description, or it may be a quantitative value or set of values such as a quotient or range. Discussion of risk estimates, such as the hazard quotient must identify the strengths and limitations of the assessment in such a way as to provide complete and useful information for decision makers.

To fully characterize the potential risks at a contaminated site, all data must be presented clearly, and in the context of the associated endpoints from the CSM. Toxicity and exposure parameters, any professional judgments, any inferences applied to the data, and all sources must be described. The discussion must also consider the following; whether NOAEL or LOAEL were used to develop TRVs; whether the intake represented a receptor with average exposure or RME; whether information was site-specific or default values were used; whether field data is available.

The conclusion of a risk assessment may be authenticated by using lines of evidence to interpret risk (USEPA, 1997a). Lines of evidence may be derived from several sources or by different techniques such as hazard quotient estimates, modeling results, field experiments, and observations. Some of the factors that must be evaluated in the risk assessment are listed below:

- The relevance of evidence to assessment endpoints.
- The relevance of evidence to the CSM.
- The quality of data and study design used from the extrapolated studies.
- The strength of the cause and effect relationships.
- The relative uncertainties associated with the lines of evidence and their direction.

ADEC may require calculation of ecological risk-based cleanup levels based off of the SLERA or to proceed directly to a BERA.

4.4.1 Hazard Quotient Risk Calculations

To characterize wildlife risks, conservative intake estimates are compared to TRVs using the HQ method. To assess risks to receptor groups, like plants, soil invertebrates, and benthic life,

measured chemical concentrations in soil, sediment, and water are compared to ecological risk-based benchmarks. The ratio of the media concentration to the benchmark may also be thought of as an HQ. Compounds that exceed an HQ of 1 must be retained for further ecological evaluation and possible development of site-specific, risk-based, ecological cleanup levels. Quotient calculations are presented below:

$$HQ = \frac{Dose}{TRV} \qquad \text{OR} \qquad HQ = \frac{MEC}{Benchmark}$$

Where:

HQ	=	hazard quotient (no units)
Dose	=	estimated contaminant intake as determined in the exposure estimate (mg/kg-day)
MEC	=	measured environmental concentration (e.g., mg/kg)
TRV	=	toxicity reference value (see subsection 4.3.1.4)
Benchmark	=	ecological screening benchmark (see subsection 4.3.1.2)

An HQ greater than 1 for a compound is interpreted by ADEC as a level at which a potential adverse ecological effect may occur in the SLERA. These contaminants must be retained for further evaluation in a BERA or development of site-specific, risk-based, ecological cleanup levels to meet regulatory requirements.

Chemicals with HQs less than 1 generally need only be retained for uncertainty assessment. However, when a cumulative effect is suspected or known, the HI must be calculated, and all HQs contributing to the HI must be retained for further evaluation in the risk assessment. The HI is the summation of all of the HQs corresponding to the particular contaminant for all pathways for each media. If the HI exceeds unity, then the individual HQs must be retained for further evaluation in the risk assessment.

The HI calculation is described below:

$$HI = \Sigma\ HQ \text{ with similar toxicological endpoints}$$

If the HI is less than 1, yet the chemical has potential to bioaccumulate, it must be retained for further evaluation in the risk assessment during the SLERA.

4.4.2 Toxicity Testing Results

Toxicity tests provide direct evidence as to whether chemicals in environmental media have potential to adversely affect living organisms. The effects typically evaluated include survival, growth, and reproduction. If toxicity tests are conducted for the ERA at a site, test organism survival, growth, and reproduction in site samples must be statistically compared to these endpoints in the laboratory control and site-specific background samples to quantify adverse effects. The results must be summarized in the ERA report, and the complete laboratory bioassay report must be attached as an appendix. Whether the test results agree with risk predictions based on benchmark comparisons must be evaluated and discussed.

4.5 Uncertainty Assessment

Uncertainty can be associated with: (1) exposure parameters, BAFs, and other information taken from the literature; (2) extrapolations used in developing a screening-level benchmark or TRV; (3) site data, or the lack thereof; and (4) elements of the CSM, such as chemical fate-and-transport and wildlife use of the site. In the uncertainty assessment section of the ERA, the risk assessor must list important sources of uncertainty and describe whether they result in an underestimate or overestimate of ecological risk at the site. Highly uncertain parameters and assumptions that, if better understood, could alter the conclusions of the assessment are the most important to identify. Such sources of uncertainty may require collection of additional site-specific data before a risk management decision can be made. USEPA (1997a and 1998 and Warren-Hicks and Moore (1998) provide additional information regarding identifying, assessing, and limiting sources of uncertainty, and discuss the difference between uncertainty and variability in ERAs.

5.0 REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). (2013 March). *Minimal Risk Levels.* Retrieved from http://www.atsdr.cdc.gov/mrls/index.asp.

Alaska Department of Environmental Conservation (ADEC). (2017). *Fate and Transport Modeling Guidance.* Division of Spill Prevention and Response, Contaminated Sites Program. Retrieved from http://dec.alaska.gov/spar/csp/guidance-forms.

ADEC. (1999a June). *User's Guide for Selection and Application of Default Assessment Endpoints and Indicator Species in Alaskan Ecoregions.* Division of Spill Prevention and Response, Contaminated Sites Program. Retrieved from http://dec.alaska.gov/spar/csp/guidance-forms.

ADEC. (1999b June). *Ecoregions/Assessment Endpoint Project Technical Background Document for Selection and Application of Default Assessment Endpoints and Indicator Species in Alaskan Ecoregions.* Division of Spill Prevention and Response, Contaminated Sites Program. Retrieved from http://dec.alaska.gov/spar/csp/guidance-forms

ADEC. (2017 January). *Policy Guidance on Developing Conceptual Site Models.* Division of Spill Prevention and Response, Contaminated Sites Program. Retrieved from http://dec.alaska.gov/spar/csp/guidance-forms.

ADEC. (2017 November). *Vapor Intrusion Guidance for Contaminated Sites.* Division of Spill Prevention and Response, Contaminated Sites Program. Retrieved from http://dec.alaska.gov/spar/csp/guidance-forms.

ADEC. (2013). *Sediment Quality Guidelines: Technical Memorandum.* Division of Spill Prevention and Response, Contaminated Sites Program. Retrieved from http://dec.alaska.gov/spar/csp/guidance-forms.

ADEC. (2014 March). *Ecoscoping Guidance: A Tool for Developing an Ecological Conceptual Site Model.* Division of Spill Prevention and Response, Contaminated Sites Program. Retrieved from http://dec.alaska.gov/spar/csp/guidance-forms.

ADEC. (2018b). *Procedures for Calculating Cumulative Risk.* Division of Spill Prevention and Response, Contaminated Sites Program. Retrieved from http://dec.alaska.gov/spar/csp/guidance-forms.

ADEC. (2018a). *Procedures for Calculating Cleanup Levels.* Division of Spill Prevention and Response, Contaminated Sites Program. Retrieved from http://dec.alaska.gov/spar/csp/guidance-forms.

Alaska Department of Fish and Game (ADF&G). (2013). *Community Subsistence Information System.* Division of Subsistence. Retrieved from http://www.adfg.alaska.gov/sb/CSIS/.

Alloway, B. J. (1990). *Heavy Metals in Soils.* Blackie & Sons, Ltd. Distributed in the United States and Canada by John Wiley & Sons, Inc.

Baes III, C. F., R. D. Sharp, A. L. Sjoreen, & R. W. Shor. (1984). *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides.* ORNL-5786. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Bechtel Jacobs Company LLC. (1998a August). *Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation.* BJC/OR-112. Oak Ridge, Tennessee: Oak Ridge National Laboratory. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/bjcor-112a1.pdf.

Bechtel Jacobs Company LLC. (1998b September). *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants.* BJC/OR-133. Oak Ridge, Tennessee: Oak Ridge National Laboratory. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/bjcor-133.pdf.

Buchman, M. F. (2008). *NOAA Screening Quick Reference Tables, NOAA OR&R Report 08-1.* Seattle, Washington: Office of Response and Restoration Division, National Oceanic and Atmospheric Administration. Retrieved from http://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf.

Calabrese, E. J. & L. A. Baldwin. (1993). *Performing Ecological Risk Assessments.* Chelsea, Michigan: Lewis Publishers.

Code of Federal Regulations (CFR). (2011 July 1). Title 300, Part 430.

Environmental Council of the States (2007). *Identification and Selection of Toxicity Values/ Criteria for CERCLA and Hazardous Waste Site Risk Assessment in the Absence of IRIS Values.* Retrieved from http://www.ecos.org/section/committees/cross_media/ecos_dod_sustainability_work_group/emerging_contaminants_task_group/

Efroymson, R. A., M. E. Will, & G. W. Suter II. (1997a November). *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision.* ES/ER/TM-126/R2. Oak Ridge, Tennessee: Oak Ridge National Laboratory. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf.

Efroymson, R. A., M. E. Will, G. W. Suter II, & A. C. Wooten. (1997b November). *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.* ES/ER/TM-85/R3. Oak Ridge, Tennessee: Oak Ridge National Laboratory. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf.

Executive Order 13045 (1997 April). *Protection of Children from Environmental Health Risks and Safety Risks.* Federal Register Vol. 62, No. 78 Retrieved from http://www.gpo.gov/fdsys/pkg/FR-1997-04-23/pdf/97-10695.pdf.

Hickey, J. P., P. F. Landrum, & M. J. Lydy. (1993). *Quantitative Structure – Activity Relationships.* Houston,

Texas: Society of Environmental Toxicology and Chemistry Workshop.

Jones, D. S., G. W. Suter II, & R. N. Hull. (1997 November). *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision.* ES/ER/TM-95/R4. Oak Ridge, Tennessee: Oak Ridge National Laboratory. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/tm95r4.pdf.

Menzie, C., D. Burmaster, J. Freshman, & C. Callahan. (1992). *Assessment of Methods for Estimating Ecological Risk in the Terrestrial Component: A Case Study at the Baird and McGuire Superfund Site in Holbrook, Massachusetts.* Environmental Toxicology and Chemistry, *11*, 245–260.

National Research Council (NRC). (1994). *Science and Judgment in Risk Assessment.* Washington, DC: National Academy of Sciences Press.

Sample, B. E., & C. A. Arenal. (1999). *Allometric Models for Interspecies Extrapolation of Wildlife Toxicity Data.* Bulletin Environmental Contamination Toxicology, *62*, 653-663.

Sample, B. E., & G. W. Suter II. (1994 September). *Estimating Exposure of Terrestrial Wildlife to Contaminants – DRAFT.* ES/ER/TM-125. Oak Ridge, Tennessee: Oak Ridge National Laboratory, Environmental Sciences Division. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/tm125.pdf.

Sample, B. E., D. M. Opresko, & G. W. Suter II. (1996 June). *Toxicological Benchmarks for Wildlife: 1996 Revision.* ES/ER/TM-86/R3. Oak Ridge, Tennessee: Risk Assessment Program, Health Sciences Research Division. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/tm86r3.pdf.

Sample, B. E., J. J. Beauchamp, R. A. Efroymson, & G. W. Suter II. (1998a February). *Development and Validation of Bioaccumulation Models for Small Mammals.* ES/ER/TM-219. Oak Ridge, Tennessee: Oak Ridge National Laboratory. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/tm219.pdf.

Sample, B. E., J. J. Beauchamp, R. A. Efroymson, G. W. Suter II, & T. L. Ashwood. (1998b February). *Development and Validation of Bioaccumulation Models for Earthworms.* ES/ER/TM-220. Oak Ridge, Tennessee: Oak Ridge National Laboratory. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/tm220.pdf.

Sample, B. E., M. S. Aplin, R. A. Efromyson, G. W. Suter II, & C. J. E. Welsh. (1997 October). *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants.* ORNL/TM-13391. Oak Ridge, Tennessee: Oak Ridge National Laboratory. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/tm13391.pdf.

Suter II, G. W. (1996 July). *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Freshwater Biota.* Environmental Toxicology and Chemistry, *15,* 1232–1241.

Suter II, G. W., & C. L. Tsao. (1996 June). *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.* ES/ER/TM-96/R2. Oak Ridge, Tennessee: Risk

Assessment Program, Health Sciences Research Division. Retrieved from http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf.

United States Environmental Protection Agency (USEPA). (1986 September). *Guidelines for the Health Risk Assessment of Chemical Mixtures.* EPA/630/R-98/002 Washington, DC Retrieved from http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=4487.

USEPA. (1988a October). *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA – Interim Final.* EPA/540/G-89/004 OSWER Directive 9355.3-01. Washington, DC: Office of Emergency and Remedial Response. Retrieved from http://www.epa.gov/superfund/policy/remedy/pdfs/540g-89004-s.pdf.

USEPA. (1988b). *Protocols for Short Term Toxicity Screening of Hazardous Waste Sites.* EPA 600/3-88/029 PB88 235 510/AS ERL-COR-496. Corvallis, Oregon: Corvallis Environmental Research Laboratory, Ecotoxicology Branch, Hazardous Waste Assessment Team.

USEPA. (1989a December). *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A) – Interim Final.* EPA/540/1-89/002. Washington, DC: Office of Emergency and Remedial Response. Retrieved from http://www.epa.gov/oswer/riskassessment/ragsa/pdf/preface.pdf.

USEPA. (1989b March). *Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual – Interim Final.* EPA/540/1-89/001. Washington, DC: Office of Emergency and Remedial Response. Retrieved from http://rais.ornl.gov/documents/RASUPEV.pdf.

USEPA. (1991a December). *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference.* EPA/540/R-92/003. Corvallis, Oregon: Environmental Research Laboratory. Retrieved from http://rais.ornl.gov/documents/ECOASR.PDF.

USEPA. (1992a April). *Guidance for Data Usability in Risk Assessment (Part A) – Final.* Publication 9285.7-09A PB92-963356. Washington, DC: Office of Emergency and Remedial Response. Retrieved from http://www.epa.gov/oswer/riskassessment/datause/pdf/datause-parta.pdf.

USEPA. (1993a July). *Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons.* EPA/600/R-93/089. Washington, DC: Office of Health and Environmental Assessment, Office of Research and Development. Retrieved from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=49732.

USEPA. (1993b December). *Wildlife Exposure Factors Handbook Volumes I and II.* EPA/600/R-93/187. Washington, DC: Office of Health and Environmental Assessment, Office of Research and Development. Retrieved from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2799.

USEPA. (1994a September). *ECO Update: Catalogue of Standard Toxicity Tests for Ecological Risk Assessment.* Publication 9345.0-05I EPA 540-F-94-013 PB94-963304. Office of Solid Waste and Emergency Response. Intermittent Bulletin Vol. 2, No. 2.

USEPA. (1994b September). *ECO Update: Using Toxicity Tests in Ecological Risk Assessment.* Publication

9345.0-05I EPA 540-F-94-012 PB94-963303. Office of Solid Waste and Emergency Response. Intermittent Bulletin Vol. 2, No. 1.

USEPA. (1997a June). *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final.* EPA 540-R-97-006 OSWER 9285.7-25 PB97-963211. Solid Waste and Emergency Response. Retrieved from http://www.epa.gov/oswer/riskassessment/ecorisk/pdf/intro.pdf.

USEPA. (1997b June). *EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund.* EPA 910-R-97-005. Office of Environmental Assessment, Risk Evaluation Unit. Retrieved from http://yosemite.epa.gov/r10/OMP.NSF/webpage/EPA+Region+10+Supplemental+Ecological+Risk+Assessment+Guidance+for+Superfund/$FILE/r0rags97.pdf.

USEPA. (1997c August). *Exposure Factors Handbook.* EPA/600/P-95/002Fa. Washington, DC: Office of Research and Development, National Center for Environmental Assessment. Retrieved from http://epa-prgs.ornl.gov/radionuclides/EFH_Final_1997_EPA600P95002Fa.pdf.

USEPA. (1998 April). *Guidelines for Ecological Risk Assessment.* EPA/630/R-95/002F. Washington, DC: Risk Assessment Forum. Retrieved from http://www.epa.gov/raf/publications/pdfs/ECOTXTBX.PDF.

USEPA. (1999). *Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.* EPA 841-B-99-002. Washington, DC: Office of Water. Retrieved from http://www.epa.gov/owow/monitoring/rbp/download.html.

USEPA. (2000a February). *Appendix to Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment – Status and Needs.* EPA-823-R-00-002. Washington, DC: Office of Water. Retrieved from http://www.epa.gov/ost/cs/biotesting/.

USEPA. (2000b February). *Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment: Status and Needs.* EPA-823-R-00-001. Washington, DC: Office of Water, Bioaccumulation Analysis Workgroup. Retrieved from http://water.epa.gov/polwaste/sediments/cs/upload/bioaccum.pdf.

USEPA. (2000c January). *Data Quality Objectives Process for Hazardous Waste Site Investigations – EPA QA/G-4HW Final.* EPA/600/R-00/007. Washington, DC: Office of Environmental Information. Retrieved from http://www.epa.gov/quality/qs-docs/g4hw-final.pdf.

USEPA. (2000d July). *Guidance for Data Quality Assessment: Practical Methods for Data Analysis.* EPA/600/R-96/084. Washington, DC: Office of Environmental Information. Retrieved from http://www.epa.gov/region6/qa/qadevtools/mod4references/secondaryguidance/g9-final.pdf.

USEPA. (2000e March). *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates, Second Edition.* EPA/600/R-99/064. Washington, DC: Office of Science and Technology, Office of Water. Retrieved from http://water.epa.gov/polwaste/sediments/cs/upload/freshmanual.pdf.

USEPA. (2000f August). *Supplemental Guidance for Conducting Health Risk Assessment of Chemical Mixtures.* EPA/630/R-00/002. Washington, DC. Retrieved http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=20533.

USEPA (2000g December). *Science Policy Council Handbook Risk Characterization.* EPA 100-B-00-002. Washington, D.C. Office of Science Policy, Office of Research and Development. Retrieved from http://www.epa.gov/risk/risk-characterization.htm

USEPA. (2001a March). *Methods for Assessing Chronic Toxicity of Marine and Estuarine Sediment-associated Contaminants with Amphipod Leptocherius plumulosus.* EPA-600/R-01/020. Retrieved from http://water.epa.gov/polwaste/sediments/cs/leptofact.cfm.

USEPA. (2001b August). *Review of Adult Lead Models Evaluation of Models for Assessing Human Health Risks Associated with Lead Exposures at Non-residential areas of Superfund and Other Hazardous Waste Sites.* EPA OSWER #9285.7-46. Washington DC: Office of Solid Waste and Emergency Response. Retrieved from http://www.epa.gov/superfund/lead/products/adultreview.pdf.

USEPA. (2002a March). *Blood Lead Concentrations of U.S. Adult Females: Summary Statistics from Phase I and Phase II of the National Health and Nutrition Evaluation Survey (NHANES III).* OSWER 9285.7-52. Office of Solid Waste and Emergency Response. Retrieved from http://www.epa.gov/superfund/programs/lead/products/nhanes.pdf.

USEPA. (2002b December). *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites.* OSWER 9285.6-10. Washington DC: Office of Emergency and Remedial Response. Retrieved from http://www.epa.gov/oswer/riskassessment/pdf/ucl.pdf.

USEPA. (2002c September). *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites.* EPA 540-R-01-003 OSWER 9285.7-41. Washington, DC: Office of Emergency and Remedial Response. Retrieved from http://www.epa.gov/oswer/riskassessment/pdf/background.pdf.

USEPA. (2002d April). *Role of Background in the CERCLA Cleanup Program.* OSWER 9285.6-07P. Washington DC: Office of Emergency and Remedial Response, Office of Solid Waste and Emergency Response. Retrieved from http://www.epa.gov/oswer/riskassessment/pdf/role.pdf.

USEPA. (2002e October). *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Fourth Edition.* EPA-821-R-02-013. Washington, DC: Office of Water. Retrieved from http://water.epa.gov/scitech/methods/cwa/wet/upload/2007_07_10_methods_wet_disk3_ctf.pdf.

USEPA. (2002f October). *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms, Third Edition.* EPA-821-R-02-014. Washington, DC: Office of Water. Retrieved from http://water.epa.gov/scitech/methods/cwa/wet/upload/2007_07_10_methods_wet_disk1_ctm.pdf.

USEPA. (2002g December). *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* OSWER 9355.4-24. Washington DC: Office of Emergency and Remedial Response. Retrieved from http://www.epa.gov/superfund/resources/soil/ssg_main.pdf.

USEPA. (2003a January). *Adult Lead Model (ALM) Spreadsheet.* Retrieved from http://www.epa.gov/superfund/lead/products.htm.

USEPA. (2003b October). *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment.* EPA/630/P-02/004F. Washington, DC: Risk Assessment Forum. Retrieved from http://www.epa.gov/raf/publications/pdfs/GENERIC_ENDPOINTS_2004.PDF.

USEPA. (2003c April). *Human Health Toxicity Values in Superfund Risk Assessments.* OSWER Directive 9285.7-53. Washington DC: Office of Solid Waste and Emergency Response. Retrieved from https://fortress.wa.gov/ecy/clarc/FocusSheets/httpwwwepagovoswerriskassessmentpdfhhmemo.pdf.

USEPA. (2003d January). *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil.* EPA-540-R-03-001. Technical Review Workgroup for Lead. Retrieved from http://www.epa.gov/superfund/lead/products/adultpb.pdf.

USEPA. (2004a). *Provisional Peer Reviewed Toxicity Values for Superfund.* Washington, DC: Office of Superfund Remediation and Technology Innovation. Retrieved from http://hhpprtv.ornl.gov/.

USEPA. (2004b). *Metal Mixtures and Children's Health.* Retrieved from http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/7978.

USEPA. (2004c July). *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) – Final.* EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312. Washington, DC: Office of Superfund Remediation and Technology Innovation. Retrieved from http://www.epa.gov/oswer/riskassessment/ragse/pdf/part_e_final_revision_10-03-07.pdf.

USEPA (2004d August) Persistent, Bioaccumulative, and Toxic (PBT) Profiler, Office of Pollution Prevention and Toxics, http://www.pbtprofiler.net/

USEPA. (2005a March). *Guidelines for Carcinogen Risk Assessment.* EPA/630/P-03/001F. Washington, DC: Risk Assessment Forum. Retrieved from http://www.epa.gov/raf/publications/pdfs/CANCER_GUIDELINES_FINAL_3-25-05.PDF.

USEPA. (2005c March). *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens.* EPA/630/R-03/003F. Washington, DC: Risk Assessment Forum. Retrieved from http://www.epa.gov/raf/publications/pdfs/childrens_supplement_final.pdf. USEPA. (2007b March). *Framework for Metals Risk Assessment.* EPA 120/R-07/001. Washington, DC: Office of the Science Advisor, Risk Assessment Forum. Retrieved from http://www.epa.gov/raf/metalsframework/pdfs/metals-risk-assessment-final.pdf.

USEPA. (2018a September). *Child-Specific Exposure Factors Handbook.* EPA/600/R-06/096F. Washington, DC: National Center for Environmental Assessment, Office of Research and Development. Retrieved from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=199243.

USEPA. (2018b May). *Regional Screening Levels for Chemical Contaminants at Superfund Sites.* Retrieved from http://epa-prgs.ornl.gov/chemicals/index.html.

USEPA. (2009a June). *Integrated Exposure Uptake Biokinetic Model for Lead in Children Version 1.1, build 264.* Retrieved from http://www.epa.gov/superfund/lead/products.htm.

USEPA. (2009b January). *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Guidance for the Calculation of Cancer and Non- Cancer Risk from Inhalation Exposures).* Retrieved from http://www.epa.gov/oswer/riskassessment/ragsf/index.htm.

USEPA (2011) *Exposure Factor Handbook: 2011 Edition.* Retrieved from http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252

USEPA (2012) *Recommendations for Default Value for Relative Bioavailability of Arsenic in Soil.* OSWER #9200.1-113. Washington, D.C.: United States Environmental Protection Agency, Office of Solid Waste and Emergency Response. http://www.epa.gov/superfund/bioavailability/guidance.htm.

USEPA. (2013a). *Tier 3 Toxicity Value White Paper.* Retrieved from http://www.epa.gov/oswer/riskassessment/pdf/tier3-toxicityvalue-whitepaper.pdf

USEPA. (2013b). *ProUCL Version 5.0.00.* Retrieved from http://www.epa.gov/nerlesd1/tsc/form.htm.

USEPA (2013c). *Ecotox Database.* Retrieved from http://cfpub.epa.gov/ecotox/.

USEPA (2014). *Tier 3 Toxicity Value White Paper.* OSWER 9285.7-86. Retrieved from http://www.epa.gov/oswer/riskassessment/superfund_toxicity.htm

USEPA (2014a) *Risk Assessment Forum White Paper: Probabilistic Risk Assessment Methods and Case Studies.* Retrieved from : http://www2.epa.gov/osa/risk-assessment-forum-white-paper-probabilistic-risk-assessment-methods-and-case-studies

van den Berg, M., L.S. Birnbaum, M. Denison, et al. (2006) *The 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds.* Toxicology Science 93(2):223–241.

Walker, J. D. (2004). *Quantitative Structure-Activity Relationships for Pollution Prevention, Toxicity Screening, Risk Assessment, and Web Applications* (pp. 280). Pensacola, Florida: SETAC Press.

Warren-Hicks, W. J., & D. R. J. Moore. (1998). *Uncertainty Analysis in Ecological Risk Assessment, proceedings from the Pellston Workshop on Uncertainty Analysis in Ecological Risk Assessment – August 23 to 28, 1995, Pellston, Michigan.* Pensacola, Florida: Society of Environmental Toxicology and Chemistry (SETAC).

6.0 GLOSSARY

The glossary for the ADEC Risk Assessment Procedures Manual defines some commonly used terms in risk assessment.

acute exposure: Exposure over a short period. Up to two weeks.

ambient: Naturally occurring background amounts of a substance in a particular environmental medium; may also refer to existing amounts in a medium, regardless of source.

applicable or relevant and appropriate requirements (ARARs): Requirements, including cleanup standards, standards of control, and other substantive environmental protection requirements and criteria for hazardous substances as specified under federal and state statutes and regulations, that must be met to comply with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund), 42 U.S.C. 9601 - 42 U.S.C.9675.

background concentration: The concentration of a hazardous substance that is consistently present in the environment or in the vicinity of a site and that is naturally present or is the result of human activities unrelated to a discharge or release at the site. See also, definition in 18 AAC 75.990(6).

bias: An inadequacy in experimental design that leads to results or conclusions not representative of the population under study.

bioaccumulation: The absorption, via breathing, eating, drinking, or active uptake, and concentration of a substance in plants or animals.

bioconcentration: The accumulation of a chemical in tissues of an organism (such as fish) to levels that are greater than the level in the medium (such as water) in which the organism resides.

bioconcentration factor: A measure of the tendency for a chemical to accumulate; the ratio of the concentration of a substance in a living organism (mg/kg) to the concentration of that substance in the surrounding environment (mg/L for aquatic systems).

biomagnification: Process by which substances such as pesticides or heavy metals move up the food chain, becoming more concentrated with each succeeding step up the chain.

cancer: The uncontrolled, invasive growth of cells. Cancerous cells can metastasize; they can break away from the original tumor, relocate, and grow elsewhere in the body.

carcinogen: A substance that is expected to cause cancer in nonhuman life; or for human health purposes, a substance that meets the criteria of a Group A or Group B carcinogen according to USEPA's *Guidelines for Carcinogen Risk Assessment.* See also, definition in 18 AAC 75.990(12).

characterization: Site sampling, monitoring, and analysis to determine the extent and nature of a release.

chronic: Of long duration. Repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans. Chronic exposure usually refers to long-term, low-level exposure. Chronic toxicity refers to the effects produced by such exposure. Chronic exposure may cause latent damage that does not appear until later.

compound: A substance formed by the union of two or more elements.

cumulative exposure: The summation of exposures of an organism to a chemical over a period of time.

dose: The amount of a substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism.

dose-response: A quantitative relationship between the dose of a chemical and the degree/severity of an effect caused by the chemical.

dose-response curve: A graphical presentation of the relationship between degree of exposure to a substance (dose) and observed biological effect or response.

dusts: Fine, dry, mechanically-produced particles.

ecosystem: The interacting system of a biological community and its nonliving environment. See also, the definition of environmentally sensitive area in 18 AAC 75.990.

environment: Comprises air, water, food, and soil media. Regarding air, it refers to all indoor and outdoor microenvironments, including residential and occupational settings. See also, definition of environmentally sensitive area in 18 AAC 75.990.

environmental fate: The destiny of a substance after release to the environment. Involves considerations such as transport through air, soil, and water; bioconcentration and degradation.

epidemiology: The study of the incidence and distribution of disease and toxic effects in a population.

exposure: Contact with a chemical. Some common routes of exposure are dermal (skin), oral (by mouth), and inhalation (breathing).

exposure assessment: Involves numerous techniques to identify a contaminant, contaminant source, environmental media of exposure, transport through each medium, chemical and physical transformations, routes of entry to the body, intensity and frequency of contact, and spatial and temporal concentration patterns of the contaminant. An array of techniques can be used, ranging from estimating the number of people exposed and contaminant concentrations to sophisticated methodology employing contaminant monitoring, modeling, and human biological marker measurement.

exposure scenario: A set of conditions or assumptions about sources, exposure pathways, concentrations of toxic chemicals, and populations (numbers, characteristics, and habits) that the investigator uses to evaluate and quantify exposure in a given situation.

extrapolation: Estimation of unknown values by extending or projecting from known values.

food chain: A sequence of species in which each species serves as a food source for the next species. Food chains usually begin with species that consume detritus or plant material (herbivores) and proceed to larger and larger carnivores. Example: grasshopper eaten by snake eaten by owl.

groundwater: water in the zone of saturation, also known as the zone below the water table, where permanently or seasonally all interstices are filled with water, or water beneath the surface of the soil, for purposes of evaluating whether the water will act as a transport medium for hazardous substance migration.

hazard: A source of risk that does not necessarily imply potential for occurrence. A hazard produces risk only if an exposure pathway exists and if exposure creates the possibility of adverse consequences.

hazard identification: A component of risk assessment that involves gathering and evaluating data on the types of injury or disease (for example, cancer) that might be produced by a substance and on the conditions of exposure under which injury or disease is produced.

hazard index (HI): The sum of the hazard quotients attributable to non-carcinogenic hazardous substances with similar critical endpoints. See also, definition in 18 AAC 75.990(47).

hazard quotient (HQ): The ratio of the exposure point value to the reference dose for hazardous substances. See also, definition in 18 AAC 75.990(50).

hazardous substance: An element or compound that, when it enters into the atmosphere or in or upon the water or surface or subsurface land of the state, presents an imminent and substantial danger to the public health or welfare, including but not limited to fish, animals, vegetation, or any part of the natural habitat in which they are found. See also, definition in AS 46.03.826(5).

hazardous waste: As defined in RCRA, a solid waste, or combination of solid wastes, that because of its quantity, concentration, or physical, chemical, or infectious characteristics, may cause or significantly contribute to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible illness or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed. Hazardous waste means waste within the scope of 18 AAC 62.020. See also, definition in 18 AAC 75.990(49).

human health risk: The likelihood (or probability) that a given exposure or series of

exposures may have damaged or will damage the health of individuals experiencing the exposures.

incidence (of disease): The number of new cases of a disease, usually expressed as an incidence rate; the number of new cases occurring in a population during a specified period divided by the number of persons exposed to the disease during that period.

inhalation: Drawing of air into the lungs.

intake: Amount of material inhaled, ingested, or absorbed dermally during a specified period of time.

institutional control: A measure taken to limit, prohibit, or protect against an activity that could interfere with the integrity of contaminated site cleanup activities or improvements designed to encapsulate or control residual contamination or result in human or environmental exposure to a hazardous substance. See also, definition in 18 AAC 75.990(54).

land use planning: A decision-making process to determine the future or end use of a parcel of land, considering such factors as current land use, public expectations, cultural considerations, local ecological factors, legal rights and obligations, technical capabilities, and costs.

LC_{50}: The concentration of toxicant necessary to kill 50 percent of the organisms being tested. It is usually expressed in parts per million (ppm).

likelihood: Statistical probability that an event such as harm or injury could occur as a result of exposure to a risk agent.

lowest observed effect level (LOEL): The lowest exposure level at which effects are observed. These effects may or may not be serious. On the other hand, a LOAEL (the A stands for adverse) makes a judgment on the significance of the effect.

LD: Lethal dose.

LD_{50}: The amount of a chemical that is lethal to one-half (50%) of the experimental animals exposed to it. LD_{50}s are usually expressed as the weight of the chemical per unit of body weight (mg/kg). It may be fed (oral LD_{50}), applied to the skin (dermal LD_{50}), or administered in the form of vapors (inhalation LD_{50}).

LOAEL: Lowest-Observed-Adverse-Effect-Level; the lowest dose in an experiment that produced an observable adverse effect.

LOEL: Lowest-Observed-Effect-Level; the lowest dose in an experiment that produced an observable effect.

modeling: Use of mathematical equations to simulate and predict potential events and processes.

monitoring: Measuring concentrations of substances in environmental media or in human or other biological tissues.

mortality rate: The death rate, often made explicit for a particular characteristic (for example, age, sex, or specific cause of death). A mortality rate contains three essential elements: (1) the number of people in a population group exposed to the risk of death; (2) a time factor; and (3) the number of deaths occurring in the exposed population during a certain time period.

National Priorities List (NPL): Listing of the nation's hazardous waste sites as established by CERCLA, prioritized for assessment.

NOAEL: No-Observed-Adverse-Effect-Level; the highest dose in an experiment that did not produce an observable adverse effect.

NOEL: No-Observed-Effect-Level; the dosage or exposure level at which no toxicologically significant adverse effect can be detected.

OSHA: Occupational Safety and Health Administration; a branch of the U.S. Department of Labor.

octanol-water partition coefficient (K_{OW}): A measurement of how a chemical is distributed at equilibrium between octanol and water. It is an important parameter and is used often in the assessment of environmental fate and transport for organic chemicals. Additionally, K_{ow} is a key variable used in the estimation of other properties.

organic carbon partition coefficient (K_{OC}): A measure of the tendency for organics to be adsorbed by soil and sediment.

onsite: The same or geographically contiguous property that may be divided by public or private right-of-way, provided the entrance and exit between the properties is at a crossroads intersection, and access is by crossing as opposed to going along the right-of-way. Noncontiguous properties owned by the same person but connected by a right-of-way that he/she controls and to which the public does not have access is also considered onsite property.

plume: A visible or measurable discharge or release of a hazardous substance from a given point of origin. See also, definition in 18 AAC 75.990(91).

probability: The likelihood of an event occurring expressed as a number.

public: Anyone outside the site boundary at the time of an accident or during normal operation.

public participation: The process by which public views and concerns are identified and incorporated into the ADEC decision-making process.

quantitative: Numerical for measured information, such as the dose needed to produce an effect, or the number of people affected.

remediation: A general term indicating overall cleanup and operations thereof, such as treatment, storage, or disposal; usually refers to contaminated media such as soils, groundwater, and buildings rather than waste contained in drums and stored in buildings.

risk: In risk assessment, the probability that something will cause injury, combined with the potential severity of that injury.

risk assessment: Determination of potential health effects including effects of contaminant exposure through inhalation, ingestion, dermal absorption, and other means, and the assessment of risk to human health and the environment from contaminants remaining in the land, air, or water as a result of a release; See also, definition 18 AAC 75.990(109) and AS 46.03.450.

risk characterization: The final phase of the risk assessment process that involves integration of the data and analysis involved in hazard identification, source/release assessment, exposure assessment, and dose-response assessment to estimate the nature and likelihood of adverse effects.

risk estimate: A description of the probability that organisms exposed to a specified dose of a substance (such as a chemical) will develop an adverse response (for example, cancer).

risk factor: Characteristic (such as race, sex, age, or obesity) or variable (such as smoking or occupational exposure level) associated with increased probability of a toxic effect.

risk management: Uses information from risk assessment and analysis together with information about technical resources, social, economic, and political values, and control or response options to determine means of reducing or eliminating a risk.

route of exposure: The avenue by which a substance (such as a chemical) comes into contact with an organism; such avenues include inhalation, ingestion, and dermal contact.

subchronic: Intermediate between acute and chronic toxicities.

safety: Belief that a substance will not cause injury under careful, defined circumstances of use.

site: An area that is contaminated, including areas contaminated by the migration of hazardous substances from a source area, regardless of property ownership. See also, definition in 18 AAC 75.990(115).

site characterization: Technical process used to evaluate the nature and extent of environmental contamination, which is necessary for designing of remediation measures and monitoring their effectiveness.

stakeholder: An individual or institution with a stake in the outcome of the results of the action. Specific examples noted in the report include: local residents; federal, state, and local citizen groups; federal, state, and local environmental groups; Native American governments and associations; workers, unions, industry, and economic interests; federal, state, and local

environmental, safety, and nuclear regulatory agencies; local, county, and state government; universities and research groups; "self regulators"; technical advisors and reviewers.

toxic: Harmful; poisonous.

toxicity: The quality or degree of being poisonous or harmful to plants, animals, or humans. See also, definition of toxicity index in 18 AAC 75.990.

toxicity assessment: Characterization of the toxicological properties and effects of a substance including all aspects of its absorption, metabolism, excretion, and mechanism of action, with special emphasis on the establishment of dose-response characteristics.

uncertainty factor: One of several, generally 10-fold default factors used in operationally deriving the RfD or RfC from experimental data. The factors are intended to account for (1) variation in susceptibility among the members of the human population; (2) uncertainty in extrapolating animal data to humans; (3) uncertainty in extrapolating from data obtained in a study with less than lifetime exposure; (4) uncertainty in extrapolating from a LOAEL rather than from NOAEL; and (5) uncertainty associated with extrapolation when a database is incomplete.

APPENDIX A -- SCOPING CHECKLISTS AND EXAMPLE TABLE

SCOPING MEETING CHECKLIST/SAMPLE AGENDA

✓ **Discussion Points**

- ❒ **GENERAL SITE INFORMATION**
  - o History of use
  - o Current and potential future land use
  - o Map of site
  - o Currently available relevant documents
- ❒ **PURPOSE OF ASSESSMENT**
  - o Determine risk posed by site
  - o Public concern over hazardous substances associated with a contaminated site
  - o Develop ACLs
  - o Develop preliminary remediation goals
- ❒ **USE OF DETERMINISTIC VS. PROBABILISTIC RA TECHNIQUES**
- ❒ **STUDY AREA**
  - o Boundary of study area
  - o Use of operable units
- ❒ **PRELIMINARY CSM**
  - o Human health
  - o Ecological
  - o Sensitive populations or environments
- ❒ **COPCS**
  - o Preliminary identification of COPCs
  - o ARARs
  - o Screening criteria reference for each media of concern
- ❒ **DATA GAPS**
  - o Quality and quantity of available data
  - o Additional sampling needs
  - o Upcoming sampling and analysis plans
- ❒ **DEVIATIONS FROM ADEC GUIDANCE OR USEPA PROTOCOL**
- ❒ **LINES OF COMMUNICATION**
  - o ADEC/RP roles and responsibilities
  - o Role of other programs/departments/agencies
  - o RP and ADEC team members and contact information
- ❒ **PUBLIC INVOLVEMENT**
  - o Meetings needed and schedule
  - o Public notices
- ❒ **SCHEDULE**
  - o Document deliverable schedule
  - o ADEC review
  - o Interim reports expected
  - o Fieldwork (if needed)
  - o Public review (if needed)

ADEC RISK ASSESSMENT CHECKLIST

✓ TASK*	DATE
RISK ASSESSMENT SCOPING MEETING See Scoping Meeting Checklist (ADEC Project Manager; ADEC Risk Assessment Staff; Responsible Party (RP); RP consultants and other stakeholders)	_____
SUBMIT CONCEPTUAL SITE MODELS (CSMs) identifying all potential pathways to ADEC project manager	_____
ADEC APPROVES CONCEPTUAL SITE MODELS	_____
SUBMIT RISK ASSESSMENT WORK PLAN including CSMs identifying all completed pathways and all items listed in subsection 2.2	_____
ADEC REVIEWS RISK ASSESSMENT WORK PLAN comments provided to RP	_____
SUBMIT RESPONSE TO ADEC WORK PLAN COMMENTS to ADEC project manager	_____
COMMENT RESOLUTION MEETING for the risk assessment work plan	_____
SUBMIT HUMAN HEALTH & ECOLOGICAL RISK ASSESSMENT to ADEC project manager	_____
ADEC REVIEWS RISK ASSESSMENT comments provided to RP	_____
SUBMIT RESPONSE TO ADEC RISK ASSESSMENT COMMENTS to ADEC project manager	_____
COMMENT RESOLUTION MEETING for the risk assessment	_____
ADEC APPROVES THE RISK ASSESSMENT	_____
ADEC MAKES RISK MANAGEMENT DECISION AND APPROVES ALTERNATIVE CLEANUP LEVELS, REMEDIAL ACTION, OR NO FURTHER ACTION	_____

*some tasks may occur concurrently

Table A.1 Human Health Compounds of Potential Concern Data Presentation

Media	Compound	Maximum Concentration (Qualifier)	Units	Frequency of Detection	Range of Detection Limits	Background Concentration	Screening Concentration (C/NC)	Source	COPC Flag	Rationale for Selection or Deletion

Rationale Codes:

Selection Reasons - Above Screening Level (ASL) No Screening Criteria (NSC)

Deletion Reasons - Below Screening Level (BSL)

APPENDIX B -- FIGURES

FIGURE 1
HUMAN HEALTH RISK ASSESSMENT PROCESS

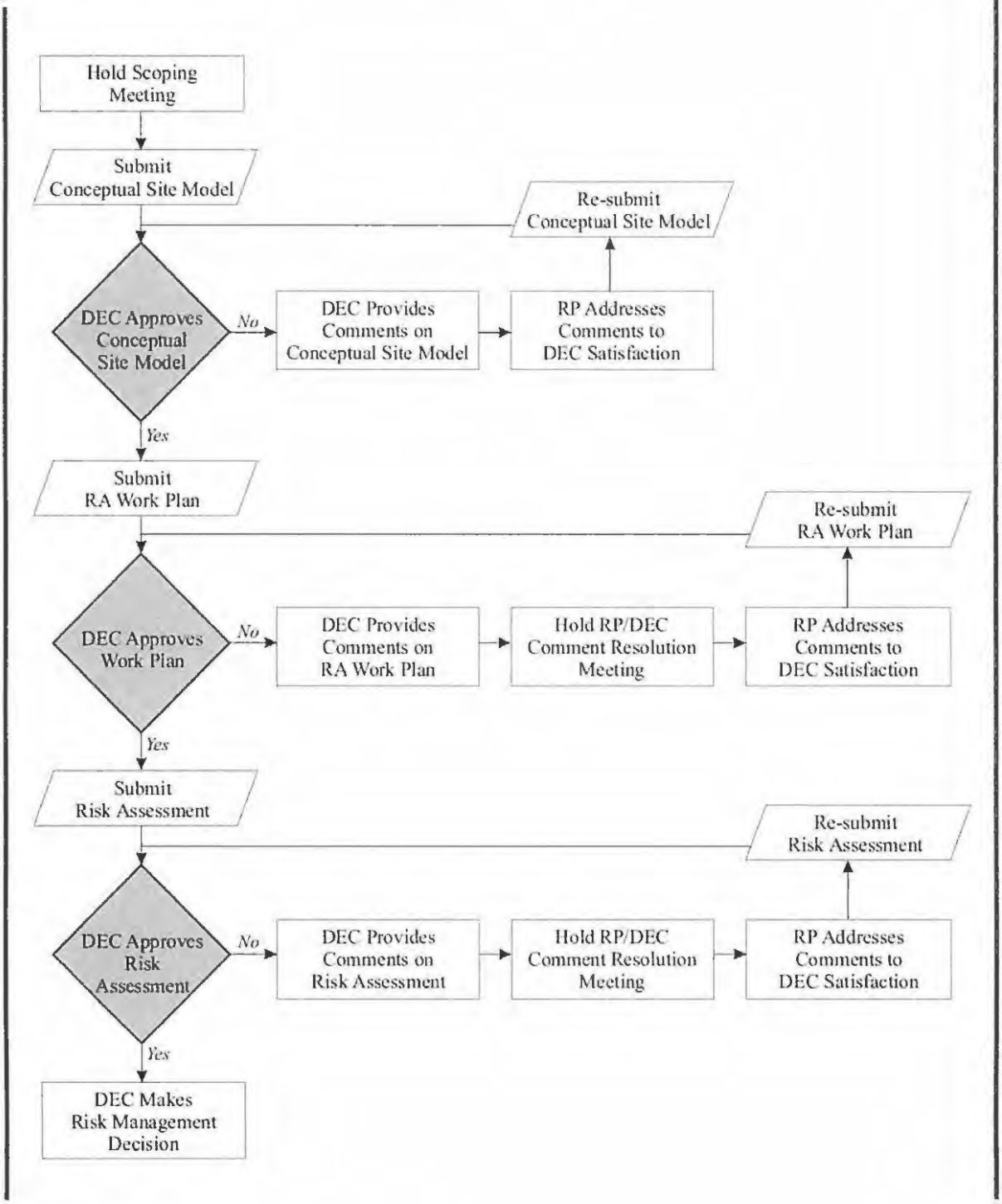


FIGURE 2
ECOLOGICAL RISK ASSESSMENT PROCESS IN ALASKA*

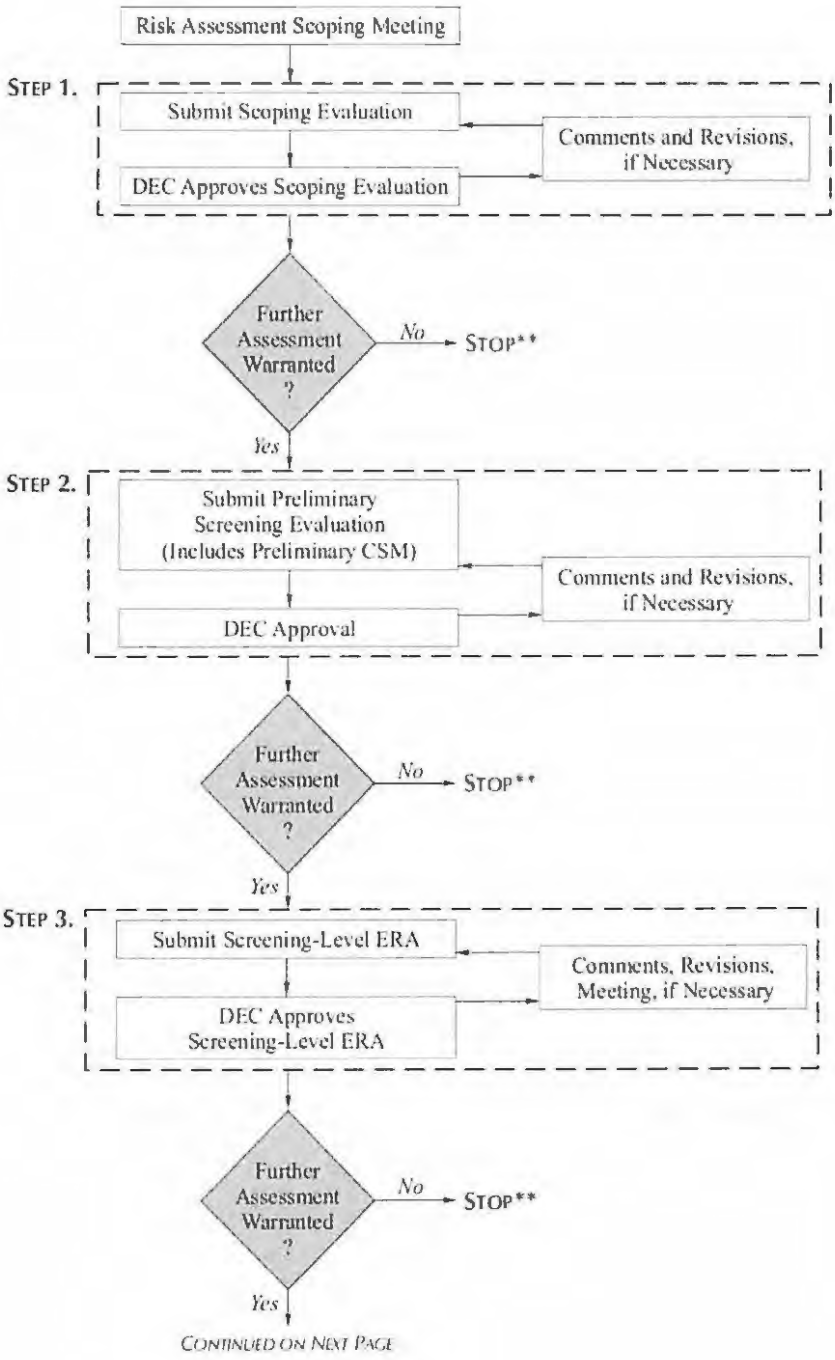
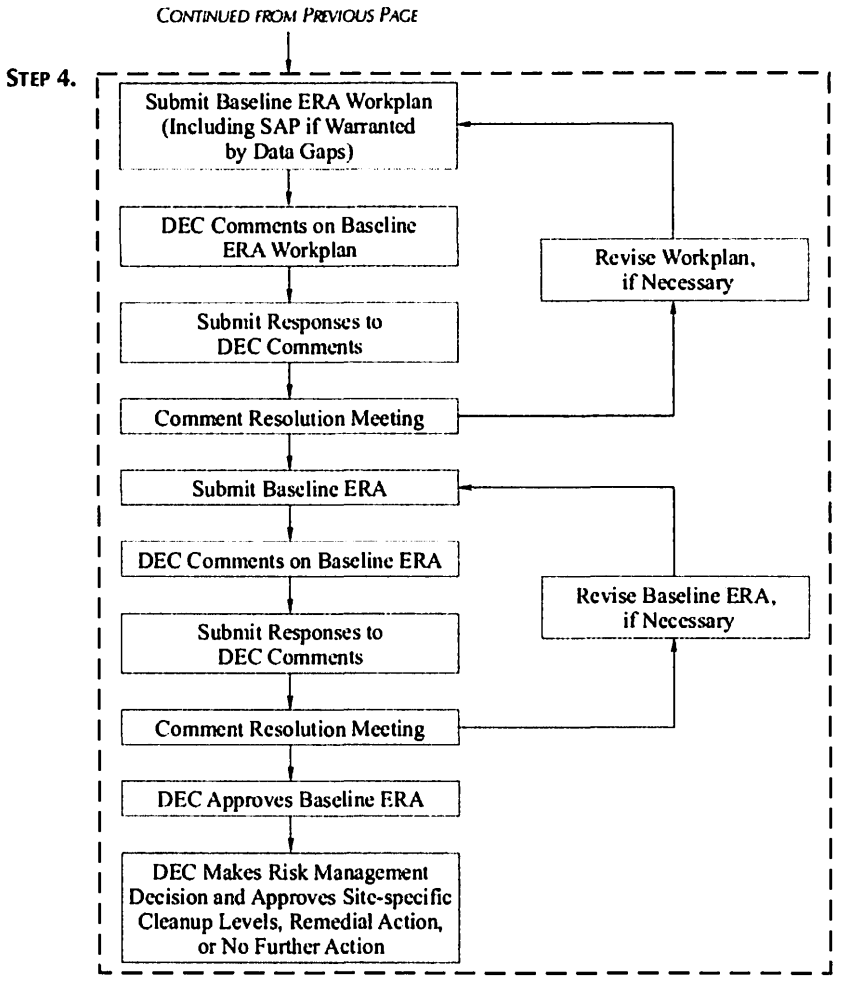


FIGURE 2
ECOLOGICAL RISK ASSESSMENT PROCESS IN ALASKA* (CONT.)



Key:

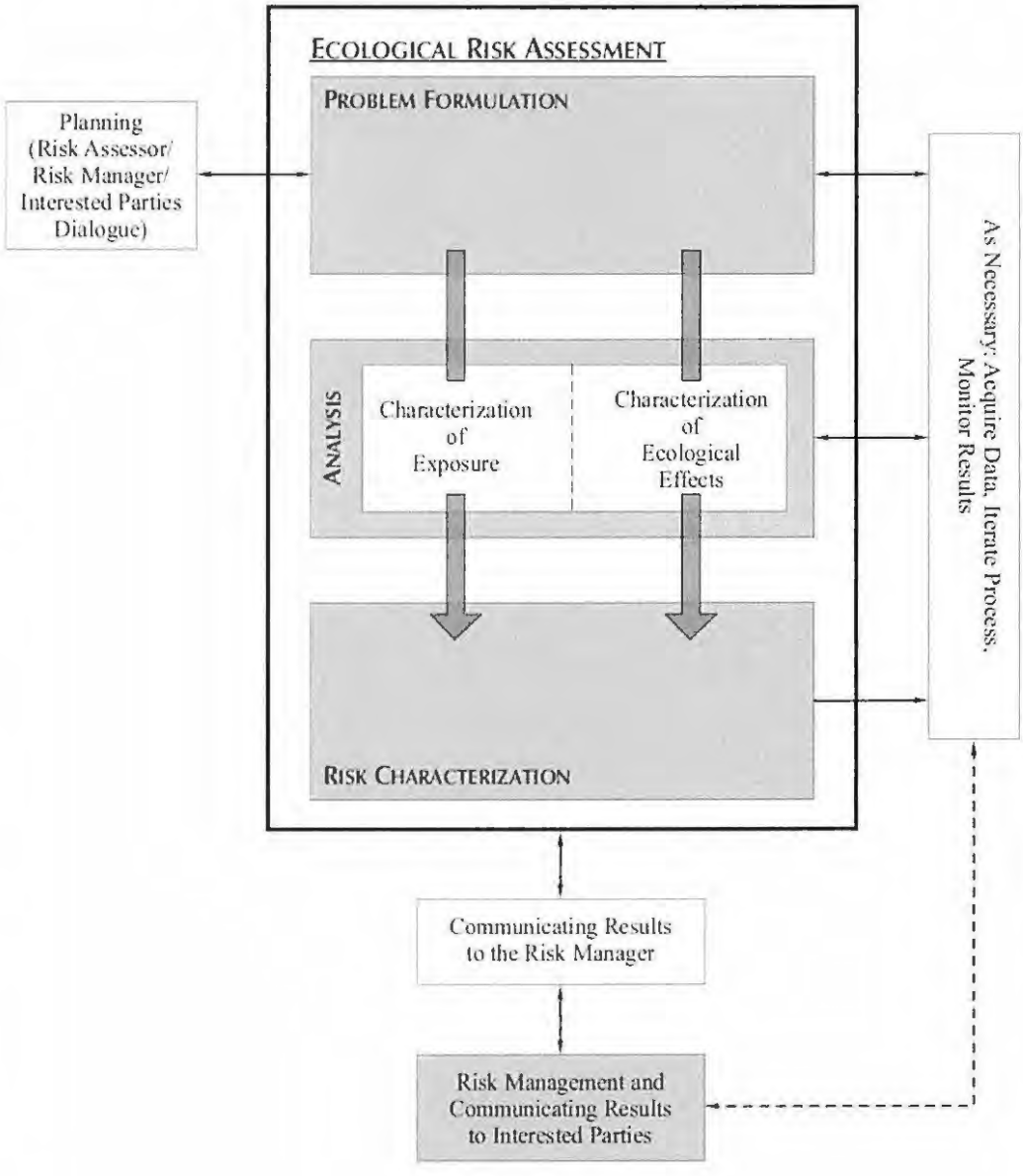
DEC	Alaska Department of Environmental Conservation
ERA	Ecological Risk Assessment
SAP	Sampling and Analysis Plan

Notes:

* Some tasks may occur concurrently.

** DEC makes risk-management decision regarding need for remedial action.

FIGURE 3
FRAMEWORK FOR ECOLOGICAL RISK ASSESSMENT (EPA 1998b)



ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF SPILL PREVENTION AND RESPONSE
CONTAMINATED SITES PROGRAM

Procedures for Calculating Cleanup Levels
February 1, 2018

Adopted by Reference at 18 AAC 75

Procedures for Calculating Cleanup Levels

TABLE OF CONTENTS

1.0 Introduction

State of Alaska Regulations at 18 AAC 75, Article 3, for Oil and Other Hazardous Substances Pollution Control, govern the cleanup of sites contaminated with oil or other hazardous substances. Sections of this regulation address the selection or development of cleanup levels for contaminated soil and groundwater that are considered protective of human health, safety, and welfare, and the environment. Cleanup levels at a site may be determined by one or more of four methods.

Method one cleanup levels listed in 18 AAC 75.341(a) and (b) apply only to soil contaminated with petroleum hydrocarbons and are not considered risk-based. Method two cleanup levels for approximately 180 chemicals are listed in 18 AAC 75.341(c) and for petroleum hydrocarbons in 18 AAC 75.341(d). These levels are generally risk-based, incorporating toxicity and chemical specific information, assessing multiple routes of exposure in climate settings that reflect the variability found across the state, and the potential for a given chemical to migrate from soil to groundwater. However, if the risk-based cleanup level exceeds the soil saturation or water solubility limit, the cleanup level is set at that limit in compliance with 18 AAC 75.325(f), which requires free product recovery. Though still somewhat generic, the method two levels are considered protective of human exposure for most sites. Determining cleanup levels under method three allows for modification of the default soil cleanup levels to account for site-specific soil and aquifer data or to propose a commercial/industrial exposure scenario. Method four cleanup levels are developed under a risk assessment conducted in accordance with the department's Risk Assessment Procedures Manual (ADEC, 2018).

This document presents the equations used to calculate the default, method two soil cleanup criteria listed in Tables B1 and B2 in 18 AAC 75.341(c) and (d) and groundwater criteria listed in Table C in 18 AAC 75.345(b)(1). The equations presented in Sections 2.0 through 5.0 for individual organic and inorganic chemicals are based on those developed for the Regional Screening Levels (RSLs) by the Oak Ridge National Laboratory under contract to the United States Environmental Protection Agency (EPA), but adapted for Alaska to account for soil and climate variability, and a default cancer risk of 1:100,000.

The equations presented in Section 6.0 for the petroleum fractions are unchanged from the 2008 version of this document. These equations were developed using the 1996 EPA Soil Screening Guidance (U.S. EPA 1996a) and information generated by the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG, 1997).

Equations are provided for the residential land use scenario only; commercial/industrial land use scenarios must be proposed under a method three (18 AAC 75.340(e)). Procedures for calculating site-specific soil cleanup levels for both Table B1 chemicals and Table B2 petroleum fractions under method three are detailed in Section 7.0.

The standardized default exposure and soil parameters developed by EPA have been used except where noted (See Table 8 for the Standard Default Parameters, found in Appendix B). These exposure parameters are designed to be protective for reasonable maximum exposure (RME)

conditions for long-term/chronic exposures, (U.S. EPA. 1991a; U.S. EPA. 1996a; U.S. EPA. 2002). Chronic oral reference doses (RfD) and chronic inhalation reference concentrations (RfC) are used to calculate non-carcinogenic concentrations. Chronic oral slope factors (CSF_o) are used to evaluate potential human carcinogenic risks. A lifetime cancer risk factor of 1×10^{-5} is used, along with a target hazard quotient (THQ) of 1, reported to one significant figure, for noncarcinogens.

For Table B1 and C compounds – equations are presented for non-carcinogenic compounds, carcinogenic compounds, and mutagenic compounds for soil and for groundwater. In addition, for vinyl chloride and trichloroethylene (TCE) in soil and groundwater, a unique set of equations are provided that adjust for early-life cancer risk estimates to derive the cleanup levels.

The groundwater cleanup calculations (Section 2.0) are broken down into equations for ingestion of groundwater, dermal contact with groundwater, and inhalation of volatiles from groundwater. The soil exposure pathway calculations (Section 3.0) are broken down into equations for dermal contact with soil, soil ingestion, and inhalation of volatiles and inhalation of soil particulates using a particulate emission factor (PEF) equation (See Section 5.0, supporting equations). Compounds considered volatile for including the inhalation pathway, are those chemicals with a Henry's Law constant greater than or equal to 1×10^{-5} atm-m^3/mole[1] or a vapor pressure greater than or equal to 1 mm Hg.

For the ingestion route, equations use an age-adjusted approach to account for the variation in soil ingestion rates for children depending on age. A number of studies have shown that inadvertent ingestion of soil is common among children six years old and younger (Calabrese et al. 1989, Davis et al. 1990, Van Wijnen et al. 1990). Therefore, the dose method uses an age-adjusted soil ingestion factor that takes into account the difference in daily soil ingestion rates, body weights, and exposure duration for children from 1 to 6 years old and others from 7 to 30 years old. This health-protective approach is chosen to take into account the higher daily rates of soil ingestion in children as well as the longer duration of exposure that is anticipated for a long-term resident. For more on this method, see RAGS Part B (U.S. EPA. 1991a).

The Table B1 method two residential soil cleanup level for the human health pathway provides a single cleanup value that does not exceed a cumulative cancer risk value of 1×10^{-5} or a THQ of 1 reported to one significant figure for noncarcinogens for all three soil exposure pathways. Likewise, the Table C groundwater cleanup value is generated by a cumulative risk calculation.

The migration to groundwater criteria for the Table B1 compounds are derived using a soil-water partitioning equation (Section 4.0). This equation back-calculates from the calculated risk-based groundwater.cleanup level. A single set of migration to groundwater criteria apply statewide for Table B1, and are based on conservative assumptions about fate and transport mechanisms in the subsurface, accounting for both (1) release of a contaminant in soil leachate and (2) transport of the contaminant through the underlying soil and aquifer to a receptor well (U.S. EPA. 2012).

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[1] The atm-m^3/mole units are obtained by multiplying the unitless value by 0.02446 (which comes from multiplying the gas constant (0.0000802 atm-m3/mole-K) by the temperature (298.16 K).

Section 5.0 presents several key equations and factors that support calculations in the proceeding sections, including the approach taken for the dermal absorption route, and derivation of the particulate emission factor, volatilization factor, and other equations.

Equations for the petroleum fraction cleanup values in Table B2 (soil) and Table C (groundwater) are presented in Section 6.0 and, as mentioned above, remain unchanged from the 2008 version of this document. Table B2 petroleum cleanup levels for migration to groundwater are climate-specific, with values established for areas of the state receiving greater than or less than 40 inches of annual precipitation. For all sites with petroleum contamination, the migration to groundwater pathway applies unless the responsible person documents that the pathway is inapplicable, such as in the Arctic zone. Table 1 provides the chemical-specific parameters for the petroleum fractions and Table 2 provides the percentage calculations for combining the aliphatic and aromatic fractions in each range.

Section 7.0 provides procedures for calculating site-specific, method three cleanup levels for the contaminants in both Tables B1 and B2. This includes both the migration-to-groundwater pathway for residential land use scenarios, and also for the commercial/industrial exposure pathways. Tables 3 through 5 list the parameters that can be modified with site-specific data for both Table B1 and B2 compounds.

Table 6 and Table 7 in Appendix A provides the toxicity and chemical-specific parameters for the organic and inorganic chemicals in Table B1 and C. These values are selected from several different references, using the following hierarchy:

- Toxicity
    - EPA's Integrated Risk Information System (IRIS)
    - Professional Peer-Reviewed Toxicity Value (PPRTV)
    - Other toxicity values
        - Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Level (MRLs)
        - California Environmental Protection Agency (Cal EPA) criteria
        - Other sources
- Organic Carbon Partition Coefficient (Koc) (L/kg)
    - Estimation Programs Interface (EPI) Suite estimated values
    - EPA Soil Screening Level (SSL) Exhibit C-1
    - Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds. Knovel, 2003 estimated values
    - EPI Suite experimental values
    - Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds. Knovel, 2003 experimental values
- Dermal Permeability Coefficient (Kp) (cm/hour)
    - EPI Suite estimated values
    - RAGS Part E.
- Effective Predictive Domain (EPD)
    - Calculated based on RAGS Part E criteria for MW and log Kow.
- Fraction Absorbed (FA)
    - RAGS Part E Exhibit B-3; Calculated.

- Molecular Weight (MW) (g/mole)
  - Syracuse Research Corporation (SRC). 2005. PHYSPROP Database. SRC. Syracuse, NY. Accessed July 2005.
  - EPI Suite
  - CRC Handbook of Chemistry and Physics
  - Perry's Chemical Engineers' Handbook (Various Editions).McGraw-Hill
  - Lange's Handbook of Chemistry (Various Editions)
  - Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds
- Water Solubility (S) (mg/L at 25 °C, unless otherwise stated in the source.).
  - SRC PHYSPROP
  - EPI experimental values
  - CRC Handbook of Chemistry and Physics
  - Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds experimental values
  - Perry's Chemical Engineers' Handbook (Various Editions).McGraw-Hill
  - Lange's Handbook of Chemistry (Various Editions)
  - Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds estimated values
  - EPI estimated values
- Unitless Henry's Law Constant (H' at 25 °C, unless otherwise stated in the source.)
  - SRC PHYSPROP
  - EPI experimental values
  - Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds experimental values
  - EPI Suite group-estimated values
  - EPI Suite bond-estimated values
- Henry's Law Constant (atm-m3/mole at 25 °C, unless otherwise stated in the source.)
  - SRC PHYSPROP
  - EPI experimental values
  - Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds experimental values
  - EPI group-estimated values
  - EPI bond-estimated values
- Diffusivity in Air (Dia) (cm2/s)
  - EPA's WATER9 equations.
- Diffusivity in Water (Diw) (cm2/s)
  - EPA's WATER9 equations.
- Soil-Water Partition Coefficient (Kd) (cm3/g).
  - SSL
  - Baes, C.F. 1984. Oak Ridge National Laboratory. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture
- Density (g/cm3)
  - CRC Handbook of Chemistry and Physics
  - Perry's Chemical Engineers' Handbook (Various Editions).McGraw-Hill

    - Lange's Handbook of Chemistry (Various Editions)
    - IRIS.
- Melting Point (MP °C)
    - SRC PHYSPROP
    - EPI experimental values
    - CRC Handbook of Chemistry and Physics
    - Perry's Chemical Engineers' Handbook (Various Editions).McGraw-Hill
    - Lange's Handbook of Chemistry (Various Editions)
    - EPI Suite estimated values
- log Octanol-Water Partition Coefficient (log Kow)
    - EPI experimental values
    - Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds experimental values
    - EPI Suite estimated values
    - Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds estimated values

Table 8 provides the list of Standard Default Parameters used in the equations in this document and calculations via which the Table B1 cleanup levels are derived.

2.0 Groundwater Cleanup Level Equations

2.1 Groundwater Cleanup Level Equation for Non-Carcinogenic Compounds

Cleanup level equations for exposure to non-carcinogenic compounds in groundwater are presented below. The terms used in the equations are defined in Appendix B. The equations include exposure routes via ingestion, dermal contact, and inhalation of volatiles, which are then totaled to produce a final value.

2.1.1 Ingestion of Water

$$CL_{water-nc-ing}(\mu g/L) = \frac{THQ \times AT_{reswc}\left(\frac{365\ days}{year} \times ED_{reswc}(6\ years)\right) \times BW_{reswc}(15\ kg) \times \left(\frac{1000\mu g}{mg}\right)}{EF_{reswc}\left(350\frac{days}{year}\right) \times ED_{reswc}(6\ years) \times \frac{1}{RfD_0\left(\frac{mg}{kg\cdot d}\right)} \times IRW_{reswc}\left(0.78\frac{L}{day}\right)}$$

2.1.2 Dermal for Inorganics

$$CL_{water-nc-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2\cdot event}\right) \times \left(\frac{1000cm^3}{L}\right)}{K_p\left(\frac{cm}{hr}\right) \times ET^{der}_{reswc}\left(0.54\ \frac{hours}{event}\right)}$$

Where:

$$DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) = \frac{THQ \times AT_{reswc}\left(\frac{365\ days}{year} \times ED_{reswc}(6\ years)\right) \times \left(\frac{1000\mu g}{mg}\right) \times BW_{reswc}(15\ kg)}{\left(\frac{1}{RfD_0\left(\frac{mg}{kg \cdot day}\right) \times GIABS}\right) \times EV_{reswc}\left(\frac{1\ events}{day}\right) \times ED_{reswc}(6\ years) \times EF_{reswc}\left(\frac{350\ days}{year}\right) \times SA_{reswc}(6{,}378\ cm^2)}$$

2.1.3 Dermal for Organics

$$\text{If } ET^{der}_{reswc}\left(0.54\ \frac{hours}{event}\right) \leq t^*(\text{hr}), \text{ then } CL_{water-nc-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2\cdot event}\right) \times \left(\frac{1000cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hr}\right)\sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times \text{If } ET^{der}_{reswc}\left(0.54\ \frac{hours}{event}\right)}{\pi}}}$$

Or,

$$\text{If } ET_{reswc}^{der}\left(0.54\ \frac{hours}{event}\right) > t^{*}(\text{hr}), \text{then } CL_{water-nc-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right)\times\left(\frac{1000cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hr}\right)\left[\frac{ET_{reswc}^{der}\left(0.54\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

2.1.4 Inhalation of Volatiles

$$CL_{water\text{-}nc\text{-}inh}(\mu g/L)=\frac{THQ\times AT_{reswc}\left(\frac{365\text{ days}}{year}\times ED_{reswc}(6\text{ years})\right)\times\left(\frac{1000\mu g}{mg}\right)}{EF_{reswc}\left(350\ \frac{days}{year}\right)\times ED_{reswc}(6\text{ years})\times ET_{reswc}^{inh}\left(\frac{24\text{ hours}}{day}\right)\times\left(\frac{1\text{ day}}{24\text{ hours}}\right)\times\frac{1}{RfC\left(\frac{mg}{m^3}\right)}\times K\ \left(\frac{0.5L}{m^3}\right)}$$

2.1.5 Total Non-carcinogenic Risk for All Groundwater Exposure Pathways

$$CL_{res-water-nc-tot}\left(\frac{\mu g}{L}\right)=\frac{1}{\frac{1}{CL_{water-nc-ing}}+\frac{1}{CL_{water-nc-der}}+\frac{1}{CL_{water-nc-inh}}}$$

2.2 Groundwater Cleanup Level Equation for Carcinogenic Compounds

Cleanup level equations for exposure to carcinogenic compounds in groundwater are presented below. The equations include exposure routes via ingestion, dermal contact, and inhalation of volatiles, which are then totaled to produce a final value.

2.2.1 Ingestion of Water

$$CL_{water-ca-ing}(\mu g/L)=\frac{TR\times AT_{resw}\left(\frac{365\ days}{year}\times LT(70\ years)\right)\times\left(\frac{1000\mu g}{mg}\right)}{CSF_0\left(\frac{mg}{kg\cdot day}\right)^{-1}\times\left(IFW_{res-adj}\left(327.95\frac{L}{kg}\right)\right)}$$

Where:

$$IFW_{res-adj}\left(327.95\frac{L}{Kg}\right)$$
$$=\frac{ED_{reswc}(6\ years)\times EF_{reswc}\left(350\frac{days}{year}\right)\times IRW_{reswc}\left(0.78\frac{L}{day}\right)}{BW_{reswc}(15\ kg)}$$
$$+\frac{[ED_{resw}(26\ years)-ED_{reswc}(6\ years)]\times EF_{reswa}\left(350\frac{days}{year}\right)\times IRW_{reswa}\left(2.5\frac{L}{day}\right)}{BW_{reswa}(80\ kg)}$$

2.2.2 Dermal for Inorganics

$$CL_{water-ca-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) \times \left(\frac{1000 cm^3}{L}\right)}{K_p\left(\frac{cm}{hr}\right) \times ET^{der}_{resw-adj}\left(0.67077 \frac{hours}{event}\right)}$$

2.2.3 Dermal for Organics

$$IF\ ET^{der}_{resw-adj}\left(0.67077 \frac{hours}{event}\right) \leq t^*(hr), then\ CL_{water-ca-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) \times \left(\frac{1000 cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hr}\right)\sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times ET^{der}_{resw-adj}\left(0.67077 \frac{hours}{event}\right)}{\pi}}}$$

Or,

$$IF\ ET^{der}_{resw-adj}\left(0.67077 \frac{hours}{event}\right) > t^*(hr), then\ CL_{water-ca-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{FA \times K_p\left(\frac{cm}{hr}\right) \times \left[\frac{ET_{resw-adj}\left(0.67077 \frac{hours}{event}\right)}{1+B} + 2 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

Where:

$$DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) = \frac{TR \times AT_{resw}\left(\frac{365\ days}{year} \times LT(70\ years)\right) \times \left(\frac{1000 \mu g}{mg}\right)}{\left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS}\right) \times DFW_{res-adj}\left(2721670 \frac{cm^2 \cdot event}{kg}\right)}$$

$$DFW_{res-adj}\left(2721670 \frac{cm^2 \cdot event}{kg}\right) = \frac{EV_{reswc}\left(\frac{1\ events}{day}\right) \times ED_{reswc}(6\ years) \times EF_{reswc}\left(350 \frac{days}{year}\right) \times SA_{reswc}(6{,}378\ cm^2)}{BW_{reswc}(15\ kg)} + \frac{EV_{reswa}\left(\frac{1\ events}{day}\right) \times ED_{reswa}(20\ years) \times EF_{reswa}\left(350 \frac{days}{year}\right) \times SA_{reswa}(20{,}900\ cm^2)}{BW_{reswa}(80 kg)}$$

And:

$$ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right) = \frac{ET^{der}_{reswc}\left(0.54\frac{hours}{event}\right) \times ED_{reswc}(6\ years) + ET^{der}_{reswa}\left(0.71\frac{hours}{event}\right) \times [ED_{resw}(26\ years) - ED_{reswc}(6\ years)]}{ED_{resw}(26\ years)}$$

2.2.4 Inhalation of Volatiles

$$CL_{water-ca-inh}(\mu g/L) = \frac{TR \times AT_{resw}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{EF_{resw}\left(\frac{350\ days}{year}\right) \times ED_{resw}(26\ years) \times ET^{inh}_{resw}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times K\left(\frac{0.5L}{m^3}\right)}$$

2.2.5 Total Carcinogenic Risk for All Groundwater Exposure Pathways

$$CL_{water-ca-tot}(\mu g/L) = \frac{1}{\frac{1}{CL_{water-ca-ing}} + \frac{1}{CL_{water-ca-der}} + \frac{1}{CL_{water-ca-inh}}}$$

2.3 Mutagenic Equation for Groundwater

Cleanup level equations for exposure to mutagenic compounds in groundwater are presented below. The equations include exposure routes via ingestion, dermal contact, and inhalation of volatiles, which are then totaled to produce a final value.

2.3.1 Ingestion of Water

$$CL_{water-mu-ing}(\mu g/L) = \frac{TR \times AT_{resw}\left(\frac{365\ days}{year} \times LT(70\ years)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1} \times IFWM_{res-adj}\left(1019.9\frac{L}{kg}\right)}$$

Where:

$$IFWM_{res-adj}\left(1019.9\frac{L}{Kg}\right) = \frac{ED_{0-2}(2\ years) \times EF_{0-2}\left(350\frac{days}{year}\right) \times IRW_{0-2}\left(0.78\frac{L}{day}\right) \times 10}{BW_{0-2}(15\ kg)} + \frac{ED_{2-6}(4\ years) \times EF_{2-6}\left(350\frac{days}{year}\right) \times IRW_{2-6}\left(0.78\frac{L}{day}\right) \times 3}{BW_{2-6}(15\ kg)} + \frac{ED_{6-16}(10\ years) \times EF_{6-16}\left(350\frac{days}{year}\right) \times IRW_{6-16}\left(2.5\frac{L}{day}\right) \times 3}{BW_{6-16}(80\ kg)} + \frac{ED_{16-60}(10\ years) \times EF_{16-30}\left(350\frac{days}{year}\right) \times IRW_{16-30}\left(2.5\frac{L}{day}\right) \times 1}{BW_{16-30}(80\ kg)}$$

2.3.2 Dermal

2.3.2.1 Dermal for Inorganics:

$$CL_{water-mu-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) \times \left(\frac{1000cm^3}{L}\right)}{K_p\left(\frac{cm}{hr}\right) \times ET_{resw-madj}\left(0.67077\frac{hours}{event}\right)}$$

2.3.2.2 Dermal for Organics:

$$IF\ ET_{resw-madj}\left(0.67077\frac{hours}{event}\right) \leq t^*(hr), then\ CL_{water-mu-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) \times \left(\frac{1000cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hr}\right)\sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times ET_{resw-madj}\left(0.67077\frac{hours}{event}\right)}{\pi}}}$$

Or

$$IF\ ET_{resw-madj}\left(0.67077\frac{hours}{event}\right) > t^*(hr), then\ CL_{water-mu-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) \times \left(\frac{1000cm^3}{L}\right)}{FA \times K_p\left(\frac{cm}{hr}\right) \times \left[\frac{ET_{resw-madj}\left(0.67077\frac{hours}{event}\right)}{1+B} + 2 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

Where:

$$DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) = \frac{TR \times AT_{resw}\left(\frac{365\ days}{year} \times LT(70\ years)\right) \times \left(\frac{1000 \mu g}{mg}\right)}{\left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS}\right) \times DFWM_{res-adj}\left(8419740 \frac{events \cdot cm^2}{kg}\right)}$$

Where:

$$DFWM_{res-adj}\left(8419740 \frac{events \cdot cm^2}{kg}\right) = \left[\left(\frac{EV_{0-2}\left(\frac{1\ events}{day}\right) \times ED_{0-2}(2\ years) \times EF_{0-2}\left(350 \frac{days}{year}\right) \times SA_{0-2}(6{,}378\ cm^2) \times 10}{BW_{0-2}(15\ kg)}\right) + \left(\frac{EV_{2-6}\left(\frac{1\ events}{day}\right) \times ED_{2-6}(4\ years) \times EF_{2-6}\left(350 \frac{days}{year}\right) \times SA_{2-6}(6{,}378\ cm^2) \times 3}{BW_{2-6}(15\ kg)}\right) + \left(\frac{EV_{6-16}\left(\frac{1\ events}{day}\right) \times ED_{6-16}(10\ years) \times EF_{6-16}\left(350 \frac{days}{year}\right) \times SA_{6-16}(20{,}900\ cm^2) \times 3}{BW_{6-16}(80\ kg)}\right) + \left(\frac{EV_{16-26}\left(\frac{1\ events}{day}\right) \times ED_{16-26}(10\ years) \times EF_{16-26}\left(350 \frac{days}{year}\right) \times SA_{16-26}(20{,}900\ cm^2) \times 1}{BW_{16-26}(80\ kg)}\right)\right]$$

And:

$$ET_{resw-madj}\left(0.67077 \frac{hours}{event}\right) = \frac{\left(\begin{array}{c} ET_{0-2}^{der}\left(0.54 \frac{hours}{event}\right) \times ED_{0-2}(2\ years) + ET_{2-6}^{der}\left(0.54 \frac{hour}{event}\right) \times ED_{2-6}(4\ years) \\ + ET_{6-16}^{der}\left(0.71 \frac{hours}{event}\right) \times ED_{6-16}(10\ years) + ET_{16-26}^{der}\left(0.71 \frac{hours}{event}\right) \times ED_{16-30}(10\ years) \end{array}\right)}{ED_{0-2}(2\ years) + ED_{2-6}(4\ years) + ED_{6-16}(10\ years) + ED_{16-26}(10\ years)}$$

2.3.3 Inhalation of Volatiles

$$CL_{water-mu-inh}(\mu g/L) = \frac{TR \times AT_{resw}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{K\left(\frac{0.5L}{m^3}\right) \times ET_{resw}^{inh}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \left[\begin{array}{c} \left(ED_{0-2}(years) \times EF_{0-2}\left(350 \frac{days}{year}\right) \times IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times 10\right) + \left(ED_{2-6}(years) \times EF_{2-6}\left(350 \frac{days}{year}\right) \times IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times 3\right) + \\ \left(ED_{6-16}(years) \times EF_{6-10}\left(350 \frac{days}{year}\right) \times IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times 3\right) + \left(ED_{16-26}(years) \times EF_{16-26}\left(350 \frac{days}{year}\right) \times IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times 1\right) \end{array}\right]$$

2.3.4 Total Mutagenic Risk for All Groundwater Exposure Pathways

$$CL_{water-mu-tot}(\mu g/L) = \frac{1}{\frac{1}{CL_{water-mu-ing}} + \frac{1}{CL_{water-mu-der}} + \frac{1}{CL_{water-mu-inh}}}$$

2.4 Vinyl Chloride

2.4.1 Ingestion of Water

$$CL_{water-vc-ing}(\mu g/L) = \frac{TR}{\frac{CSF_0\left(\frac{mg}{kg\cdot day}\right)^{-1} \times IFW_{res-adj}\left(327.95\frac{L}{kg}\right) \times \frac{mg}{1000\mu g}}{AT_{resw}\left(\frac{365\ days}{year} \times LT(70\ years)\right)} + \frac{CSF_0\left(\frac{mg}{kg\cdot day}\right)^{-1} \times IRW_{reswc}\left(0.78\frac{L}{day}\right) \times \frac{mg}{1000\mu g}}{BW_{reswc}(15\text{kg})}}$$

Where:

$$IFW_{res-adj}\left(327.95\frac{L}{kg}\right) = \frac{ED_{reswc}(6\ years) \times EF_{reswc}\left(350\frac{days}{year}\right) \times IRW_{reswc}\left(0.78\frac{L}{day}\right)}{BW_{reswc}(15\ Kg)} + \frac{[ED_{resw}(26\ years) - ED_{reswc}(6\ years)] \times EF_{reswa}\left(350\frac{days}{year}\right) \times IRW_{reswa}\left(2.5\frac{L}{day}\right)}{BW_{reswa}(80\ kg)}$$

2.4.2 Dermal

$$IF\ ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right) \leq t^*(hr), then\ CL_{water-vc-der}(\mu g/L) = \frac{DA_{event}\left(\frac{\mu g}{cm^2\cdot event}\right) \times \left(\frac{1000cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hr}\right)\sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right)}{\pi}}}$$

Or,

$$IF\ ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right) > t^{*}(hr), then\ CL_{water-vc-der}(\mu g/L)$$
$$= \frac{DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{FA \times K_p\left(\frac{cm}{hr}\right) \times \left[\frac{ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right)}{1+B} + 2 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

Where:

$$DA_{event}\left(\frac{\mu g}{cm^2 \cdot event}\right) = \frac{TR}{\left(\frac{\left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS}\right) \times DFW_{res-adj}\left(2721670\frac{cm^2 \cdot event}{kg}\right)}{AT_{resw}\left(\frac{365\ days}{year} \times \text{LT(70 years)}\right) \times \frac{1000\ \mu g}{mg}}\right) + \left(\frac{\left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS}\right) \times EV_{reswc}\left(\frac{1\ event}{day}\right) \times SA_{reswc}(6378\ cm^2)}{BW_{reswc}(15kg) \times \frac{1000\ \mu g}{mg}}\right)}$$

Where:

$$DFW_{res-adj}\left(2721670\frac{cm^2 \cdot event}{kg}\right) = \frac{EV_{reswc}\left(\frac{1\ events}{day}\right) \times ED_{reswc}(6\ years) \times EF_{reswc}\left(350\frac{days}{year}\right) \times SA_{reswc}(6{,}378\ cm^2)}{BW_{reswc}(15\ kg)} + \frac{EV_{reswa}\left(\frac{1\ events}{day}\right) \times ED_{reswa}(24\ years) \times EF_{reswa}\left(350\frac{days}{year}\right) \times SA_{reswa}(20{,}900\ cm^2)}{BW_{reswa}(80kg)}$$

And:

$$ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right) = \frac{ET^{der}_{reswc}\left(0.54\frac{hours}{event}\right) \times ED_{reswc}(6\ years) + ET^{der}_{reswa}\left(0.71\frac{hours}{event}\right) \times [ED_{resw}(26\ years) - ED_{reswc}(6\ years)]}{ED_{resw}(26\ years)}$$

2.4.3 Inhalation

$$CL_{water-vc-inh}(\mu g/L) = \frac{TR}{\left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times EF_{resw}\left(\frac{350\ days}{year}\right) \times ED_{resw}(26\ years) \times ET^{inh}_{resw}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times K\left(\frac{0.5L}{m^3}\right)}{AT_{resw}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}\right) + \left(IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times K\left(\frac{0.5L}{m^3}\right)\right)}$$

2.4.4 Total

$$CL_{water-vc-tot}(mg/kg) = \frac{1}{\frac{1}{CL_{water-vc-ing}} + \frac{1}{CL_{water-vc-der}} + \frac{1}{CL_{water-vc-inh}}}$$

2.5 Trichloroethylene

2.5.1 Ingestion of Water

$$CL_{water-tce-ing}(\mu g/L) = \frac{TR \times AT_{resw}\left(\frac{365\ days}{year} \times LT(70\ years)\right) \times \frac{(1000 \mu g)}{mg}}{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1} \times \left[\left(CAF_0(0.804) \times IFW_{resw-adj}\left(327.95 \frac{L}{kg}\right)\right) + \left(MAF_0(0.202) \times IFWM_{res-adj}\left(1019.9 \frac{L}{kg}\right)\right)\right]}$$

Where:

$$CAF_0(0.804) = \frac{CSF_0\left(0.037 \frac{mg}{kg \cdot day}\right)^{-1}\ NHL + Liver\ Oral\ Slope\ Factor}{CSF_0\left(0.046 \frac{mg}{kg \cdot day}\right)^{-1}\ Adult - Based\ Oral\ Slope\ Factor}$$

$$MAF_0(0.202) = \frac{CSF_0\left(0.0093 \frac{mg}{kg \cdot day}\right)^{-1}\ Kidney\ Oral\ Slope\ Factor}{CSF_0\left(0.046 \frac{mg}{kg \cdot day}\right)^{-1}\ Adult - Based\ Oral\ Slope\ Factor}$$

$$IFW_{res-adj}\left(327.95 \frac{L}{kg}\right) = \frac{ED_{reswc}(6\ years) \times EF_{reswc}\left(350 \frac{days}{year}\right) \times IRW_{reswc}\left(0.78 \frac{L}{day}\right)}{BW_{reswc}(15\ kg)} + \frac{[ED_{resw}(26\ years) - ED_{reswc}(6\ years)] \times EF_{reswa}\left(350 \frac{days}{year}\right) \times IRW_{reswa}\left(2.5 \frac{L}{day}\right)}{BW_{reswa}(80\ kg)}$$

$$IFWM_{res-adj}\left(1019.9 \frac{L}{Kg}\right) = \frac{ED_{0-2}(2\ years) \times EF_{0-2}\left(350 \frac{days}{year}\right) \times IRW_{0-2}\left(0.78 \frac{L}{day}\right) \times 10}{BW_{0-2}(15\ kg)} + \frac{ED_{2-6}(4\ years) \times EF_{2-6}\left(350 \frac{days}{year}\right) \times IRW_{2-6}\left(0.78 \frac{L}{day}\right) \times 3}{BW_{2-6}(15\ kg)} + \frac{ED_{6-16}(10\ years) \times EF_{6-16}\left(350 \frac{days}{year}\right) \times IRW_{6-16}\left(2.5 \frac{L}{day}\right) \times 3}{BW_{6-16}(80\ kg)} + \frac{ED_{16-26}(10\ years) \times EF_{16-26}\left(350 \frac{days}{year}\right) \times IRW_{16-26}\left(2.5 \frac{L}{day}\right) \times 1}{BW_{16-26}(80\ kg)}$$

2.5.2 Dermal

$$IF\ ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right) \le t^*(hr), then\ CL_{water-tce-der}(\mu g/L)$$

$$= \frac{DA_{tce-event}\left(\frac{\mu g}{cm^2 \cdot event}\right) \times \left(\frac{1000 cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hr}\right)\sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right)}{\pi}}}$$

Or,

$$IF\ ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right) > t^*(hr), then\ CL_{water-tce-der}(\mu g/L)$$

$$= \frac{DA_{tce-event}\left(\frac{\mu g}{cm^2 \cdot event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{FA \times K_p\left(\frac{cm}{hr}\right) \times \left[\frac{ET^{der}_{resw-adj}\left(0.67077\frac{hours}{event}\right)}{1+B} + 2 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

Where:

$$DA_{tce-event}\left(\frac{\mu g}{cm^2 \cdot event}\right)$$

$$= \frac{TR \times AT_{resw}\left(\frac{365\ days}{year} \times LT(70\ years)\right) \times \left(\frac{1000 \mu g}{mg}\right)}{\left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS}\right) \times \left[\left(CAF_0(0.804) \times DFW_{resw-adj}\left(2721670\frac{events \cdot cm^2}{kg}\right)\right) + \left(MAF_0(0.202) \times DFWM_{res-adj}\left(8419740\frac{events \cdot cm^2}{kg}\right)\right)\right]}$$

Where:

$$DFW_{res-adj}\left(2721670\frac{cm^2 \cdot event}{kg}\right)$$

$$= \frac{EV_{reswc}\left(\frac{1\ events}{day}\right) \times ED_{reswc}(6\ years) \times EF_{reswc}\left(350\frac{days}{year}\right) \times SA_{reswc}(6{,}378\ cm^2)}{BW_{reswc}(15\ kg)}$$

$$+ \frac{EV_{reswa}\left(\frac{1\ events}{day}\right) \times ED_{reswa}(20\ years) \times EF_{reswa}\left(350\frac{days}{year}\right) \times SA_{reswa}(20{,}900\ cm^2)}{BW_{reswa}(80 kg)}$$

And:

$$DFWM_{res-adj}\left(8419740\frac{events\cdot cm^2}{kg}\right)$$
$$=\left[\left(\frac{EV_{0-2}\left(\frac{1\ events}{day}\right)\times ED_{0-2}(2\ years)\times EF_{0-2}\left(350\frac{days}{year}\right)\times SA_{0-2}(6{,}378\ cm^2)\times 10}{BW_{0-2}(15\ kg)}\right)\right.$$
$$+\left(\frac{EV_{2-6}\left(\frac{1\ events}{day}\right)\times ED_{2-6}(4\ years)\times EF_{2-6}\left(350\frac{days}{year}\right)\times SA_{2-6}(6{,}378\ cm^2)\times 3}{BW_{2-6}(15\ kg)}\right)$$
$$+\left(\frac{EV_{6-16}\left(\frac{1\ events}{day}\right)\times ED_{6-16}(10\ years)\times EF_{6-16}\left(350\frac{days}{year}\right)\times SA_{6-16}(20{,}900\ cm^2)\times 3}{BW_{6-16}(80\ kg)}\right)$$
$$\left.+\left(\frac{EV_{16-30}\left(\frac{1\ events}{day}\right)\times ED_{16-26}(10\ years)\times EF_{16-26}\left(350\frac{days}{year}\right)\times SA_{16-26}(20{,}900\ cm^2)\times 1}{BW_{16-26}(80\ kg)}\right)\right]$$

And:

$$ET^{der}_{resw-madj}\left(0.67077\frac{hours}{event}\right)$$
$$=\frac{\begin{array}{c}ET^{der}_{0-2}\left(0.54\frac{hours}{event}\right)\times ED_{0-2}(2\ years)+ET^{der}_{2-6}\left(0.54\frac{hours}{event}\right)\times ED_{2-6}(4\ years)\\ +ET^{der}_{6-16}\left(0.71\frac{hours}{event}\right)\times ED_{6-16}(10\ years)+ET^{der}_{16-26}\left(0.71\frac{hours}{event}\right)\times ED_{16-26}(10\ years)\end{array}}{ED_{0-2}(2\ years)+ED_{2-6}(4\ years)+ED_{6-16}(10\ years)+ED_{16-26}(10\ years)}$$

2.5.3 Inhalation

$$CL_{water-tce-inh}\left(\frac{\mu g}{L}\right)$$
$$=\frac{TR\times AT_{resw}\left(\frac{365\ days}{year}\times \mathrm{LT}(70\ years)\right)}{ET^{inh}_{resw}\left(\frac{24\ hours}{day}\right)\times\frac{1\ day}{24\ hours}\times \mathrm{K}\left(0.5\frac{L}{m^3}\right)\times \mathrm{IUR}\left(\frac{\mu g}{m^3}\right)^{-1}}$$
$$\times\left[\begin{array}{c}\left(EF_{resw}\left(350\frac{days}{year}\right)\times ED_{resw}(26\ years)\times CAF_i(0.756)\right)+\left(ED_{0-2}(2\ years)\times EF_{0-2}\left(350\frac{days}{year}\right)\times MAF_i(0.244)\times 10\right)\\ +\left(ED_{2-6}(4\ years)\times EF_{2-6}\left(350\frac{days}{year}\right)\times MAF_i(0.244)\times 3\right)+\left(ED_{6-16}(10\ years)\times EF_{6-16}\left(350\frac{days}{year}\right)\times MAF_i(0.244)\times 3\right)\\ +\left(ED_{16-26}(10\ years)\times EF_{16-26}\left(350\frac{days}{year}\right)\times MAF_i(0.244)\times 1\right)\end{array}\right]$$

$$CAF_i(0.756)=\frac{IUR\left(3.1\times 10^{-6}\left(\frac{\mu g}{m^3}\right)^{-1}\right)\ NHL+Liver\ Unit\ Risk\ Estimate}{IUR\left(4.1\times 10^{-6}\left(\frac{\mu g}{m^3}\right)^{-1}\right)\ Adult-Based\ Unit\ Risk\ Estimate}$$

$$MAF_i(0.244)=\frac{IUR\left(1\times 10^{-6}\left(\frac{\mu g}{m^3}\right)^{-1}\right)\ Kidney\ Unit\ Risk\ Estimate}{IUR\left(4.1\times 10^{-6}\left(\frac{\mu g}{m^3}\right)^{-1}\right)\ Adult-Based\ Unit\ Risk\ Estimate}$$

2.5.4 Total

$$CL_{water-tce-tot}(\mu g/L) = \frac{1}{\frac{1}{CL_{water-tce-ing}} + \frac{1}{CL_{water-tce-der}} + \frac{1}{CL_{water-tce-inh}}}$$

3.0 Soil Cleanup Level Equations for Residential Soil

3.1 Equations for Non-Carcinogenic Compounds

Cleanup level equations for exposure to non-carcinogenic compounds in soil are presented below. The terms used in the equations are defined in Appendix B. The equations include exposure routes via ingestion, inhalation of volatiles and particulates, and dermal contact, which are then totaled to produce a final value.

3.1.1 Incidental Ingestion of Soil

$$CL_{soil-nc-ing}(mg/kg) = \frac{THQ \times AT_{ressc}\left(\frac{365\ days}{year} \times ED_{ressc}(6\ years)\right) \times BW_{ressc}(15\ kg)}{EF_{ressc}\left(\frac{days}{year}\right) \times ED_{ressc}(6\ year) \times \frac{\text{RBA}}{RfD_0\left(\frac{mg}{kg \cdot day}\right)} \times IRS_{ressc}\left(200\frac{mg}{day}\right) \times \frac{10^{-6}kg}{mg}}$$

3.1.2 Dermal Contact with Soil

$$CL_{soil-nc-der}(mg/kg) = \frac{THQ \times AT_{ressc}\left(\frac{365\ days}{year} \times ED_{ressc}(6\ years)\right) \times BW_{ressc}(15\ kg)}{EF_{ress}\left(\frac{days}{year}\right) \times ED_{ressc}(6\ year) \times \frac{1}{\left(RfD_0\left(\frac{mg}{kg \cdot day}\right) \times GIABS\right)} \times SA_{ressc}\left(2373\frac{cm^2}{day}\right) \times AF_{ressc}\left(0.2\frac{mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6}kg}{mg}}$$

3.1.3 Inhalation of Volatiles and Particulates Emitted from Soil

$$CL_{soil-nc-inh}(mg/kg) = \frac{THQ \times AT_{ressc}\left(\frac{365\ days}{year} \times ED_{ressc}(6\ years)\right)}{EF_{ressc}\left(\frac{days}{year}\right) \times ED_{ressc}(6\ year) \times ET_{ressc}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(\frac{mg}{m^3}\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{Kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{Kg}\right)}\right)}$$

3.1.4 Total Non-carcinogenic Risk for All Soil Exposure Pathways

$$CL_{soil-nc-tot}(mg/kg) = \frac{1}{\frac{1}{CL_{soil-nc-ing}} + \frac{1}{CL_{soil-nc-der}} + \frac{1}{CL_{soil-nc-inh}}}$$

3.2 Equations for Carcinogenic Compounds

Cleanup level equations for exposure to carcinogenic compounds in soil are presented below. The equations include exposure routes via ingestion, inhalation of volatiles and particulates, and dermal contact, which are then totaled to produce a final value.

3.2.1 Incidental Ingestion of Soil

$$CL_{soil-ca-ing}(mg/kg) = \frac{TR \times AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1} \times \mathrm{RBA} \times IFS_{res-adj}\left(28350\frac{mg}{kg}\right) \times \left(\frac{10^{-6}kg}{mg}\right)}$$

Where:

$$IFS_{res-adj}\left(28350\frac{mg}{kg}\right) = \frac{ED_{ressc}(6\ years) \times EF_{ressc}\left(\frac{days}{year}\right) \times IRS_{ressc}\left(\frac{200\ mg}{day}\right)}{BW_{ressc}(15\ kg)} + \frac{[ED_{ress}(26\ years) - ED_{ressc}(6\ years)] \times EF_{ressa}\left(\frac{days}{year}\right) \times IRS_{ressa}\left(\frac{100\ mg}{day}\right)}{BW_{ressa}(80\ kg)}$$

3.2.2 Dermal Contact with Soil

$$CL_{res-sol-ca-der}(mg/kg) = \frac{TR \times AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{\left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS}\right) \times DFS_{res-adj}\left(79758\frac{mg}{kg}\right) \times ABS_d \times \left(\frac{10^{-6}kg}{mg}\right)}$$

Where:

$$DFS_{res-adj}\left(79758\frac{mg}{kg}\right) = \frac{ED_{ressc}(6\ years) \times EF_{ressc}\left(\frac{days}{year}\right) \times SA_{ressc}\left(2373\frac{cm^2}{day}\right) \times AF_{ressc}\left(0.2\frac{mg}{cm^2}\right)}{BW_{ressc}(15\ kg)} + \frac{[ED_{ress}(26\ years) - ED_{ressc}(6\ years)] \times EF_{ressa}\left(\frac{days}{year}\right) \times SA_{ressa}\left(6032\frac{cm^2}{day}\right) \times AF_{ressa}\left(0.07\frac{mg}{cm^2}\right)}{BW_{ressa}(80\ kg)}$$

3.2.3 Inhalation of Volatiles and Particulates Emitted from Soil

$$CL_{soil-ca-inh}(mg/kg) = \frac{TR \times AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1000\ \mu g}{mg}\right) \times EF_{ress}\left(\frac{days}{year}\right) \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times ED_{ress}(26\ year) \times ET_{ress}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right)}$$

3.2.4 Total Carcinogenic Risk for All Soil Exposure Pathways

$$CL_{soil-ca-tot}(mg/kg) = \frac{1}{\frac{1}{CL_{soil-ca-ing}} + \frac{1}{CL_{soil-ca-der}} + \frac{1}{CL_{soil-ca-inh}}}$$

3.3 Equations for Mutagenic Compounds

Cleanup level equations for exposure to mutagenic compounds in soil are presented below. For these compounds, the exposure rates take into account age-specific susceptibility to mutagens through the use of an age dependent adjustment factor (ADAF). The equations include exposure routes via ingestion, inhalation of volatiles and particulates, and dermal contact, which are then totaled to produce a final value.

3.3.1 Incidental Ingestion of Soil

$$CL_{soil-mu-ing}(mg/kg) = \frac{TR \times AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1} \times RBA \times IFSM_{res-adj}\left(128700\frac{mg}{kg}\right) \times \left(\frac{10^{-6}kg}{mg}\right)}$$

Where:

$$IFSM_{res-adj}\left(128700\frac{mg}{kg}\right) = \frac{ED_{0-2}(2\ years) \times EF_{0-2}\left(\frac{days}{year}\right) \times IRS_{0-2}\left(200\frac{mg}{day}\right) \times 10}{BW_{0-2}(15\ kg)} + \frac{ED_{2-6}(4\ years) \times EF_{2-6}\left(\frac{days}{year}\right) \times IRS_{2-6}\left(200\frac{mg}{day}\right) \times 3}{BW_{2-6}(15\ kg)} + \frac{ED_{6-16}(10\ years) \times EF_{6-16}\left(\frac{days}{year}\right) \times IRS_{6-16}\left(100\frac{mg}{day}\right) \times 3}{BW_{6-16}(80\ kg)} + \frac{ED_{16-26}(10\ years) \times EF_{16-26}\left(\frac{days}{year}\right) \times IRS_{16-26}\left(100\frac{mg}{day}\right) \times 1}{BW_{16-26}(80\ kg)}$$

3.3.2 Dermal Contact with Soil

$$CL_{soil-mu-der}(mg/kg) = \frac{TR \times AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{\left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS}\right) \times DFSM_{res-adj}\left(330372\frac{mg}{kg}\right) \times ABS_d \times \left(\frac{10^{-6}kg}{mg}\right)}$$

Where:

$$DFSM_{res-adj}\left(330372\frac{mg}{kg}\right) = \frac{ED_{0-2}(2\ years) \times EF_{0-2}\left(\frac{days}{year}\right) \times AF_{0-2}\left(0.2\frac{mg}{cm^2}\right) \times SA_{0-2}\left(2373\frac{cm^2}{day}\right) \times 10}{BW_{0-2}(15\ kg)} + \frac{ED_{2-6}(4\ years) \times EF_{2-6}\left(\frac{days}{year}\right) \times AF_{2-6}\left(0.2\frac{mg}{cm^2}\right) \times SA_{2-6}\left(2373\frac{cm^2}{day}\right) \times 3}{BW_{2-6}(15\ kg)} + \frac{ED_{6-16}(10\ years) \times EF_{6-16}\left(\frac{days}{year}\right) \times AF_{6-16}\left(0.07\frac{mg}{cm^2}\right) \times SA_{6-16}\left(6032\frac{cm^2}{day}\right) \times 3}{BW_{6-16}(80\ kg)} + \frac{ED_{16-26}(10\ years) \times EF_{16-26}\left(\frac{days}{year}\right) \times AF_{16-26}\left(0.07\frac{mg}{cm^2}\right) \times SA_{16-26}\left(6032\frac{cm^2}{day}\right) \times 1}{BW_{16-26}(80\ kg)}$$

3.3.3 Inhalation of Volatiles and Particulates Emitted from Soil

$$CL_{soil-mu-inh}(mg/kg) = \frac{TR \times AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\begin{array}{l}\left(ED_{0-2}(2\ years) \times EF_{0-2}\left(\frac{days}{year}\right) \times ET_{0-2}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 10\right) + \left(ED_{2-6}(4\ years) \times EF_{2-6}\left(\frac{days}{year}\right) \times ET_{2-6}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 3\right) + \\ \left(ED_{6-16}(10\ years) \times EF_{6-16}\left(\frac{days}{year}\right) \times ET_{6-16}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 3\right) + \left(ED_{16-26}(10\ years) \times EF_{16-26}\left(\frac{days}{year}\right) \times ET_{6-16}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 1\right)\end{array}\right)}$$

3.3.4 Total Mutagenic Risk for All Soil Exposure Pathways

$$CL_{soil-mu-tot}(mg/kg) = \frac{1}{\frac{1}{CL_{soil-mu-ing}} + \frac{1}{CL_{soil-mu-der}} + \frac{1}{CL_{soil-mu-inh}}}$$

3.4 Equations for Vinyl Chloride

Cleanup level equations for exposure to vinyl chloride in soil are presented below. The equations include exposure routes via ingestion, inhalation of volatiles and particulates, and dermal contact, which are then totaled to produce a final value.

3.4.1 Incidental Ingestion of Soil

$$CL_{soil-vc-ing}\left(\frac{mg}{kg}\right) = \frac{TR}{\left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1} \times \text{RBA} \times IFS_{res-adj}\left(28350\frac{mg}{kg}\right) \times \frac{10^{-6}kg}{mg}}{AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}\right) + \left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1} \times \text{RBA} \times IRS_{ressc}\left(200\frac{mg}{day}\right) \times \frac{10^{-6}kg}{mg}}{BW_{ressc}(15\ kg)}\right)}$$

Where $IFS_{res\text{-}adj}$ = $IFS_{res\text{-}adj}$ from Section 3.2.1

3.4.2 Dermal Contact with Soil

$$CL_{soil-vc-der}\left(\frac{mg}{kg}\right) = \frac{TR}{\left(\frac{\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS} \times DFS_{res-adj}\left(79758\frac{mg}{kg}\right) \times ABS_d \times \frac{10^{-6}kg}{mg}}{AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}\right) + \left(\frac{\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS} \times SA_{ressc}\left(2373\frac{cm^2}{day}\right) \times AF_{ressc}\left(0.2\frac{mg}{cm^2}\right) \times ABS \times \frac{10^{-6}kg}{mg}}{BW_{ressc}(15\ kg)}\right)}$$

Where $DFS_{res\text{-}adj}$ = $DFS_{res\text{-}adj}$ from 3.2.2

3.4.3 Inhalation of Volatiles and Particulates Emitted from Soil

$$CL_{soil-vc-inh}\left(\frac{mg}{kg}\right) = \frac{TR}{\left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times EF_{ress}\left(\frac{days}{year}\right) \times ED_{ress}(26\ years) \times ET_{ress}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right) \times VF_s\left(\frac{m^3}{kg}\right)}\right) + \left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1}}{VF_s\left(\frac{m^3}{kg}\right)} \times \left(\frac{1000\ \mu g}{mg}\right)\right)}$$

3.4.4 Total Vinyl Chloride Risk for All Soil Exposure Pathways

$$CL_{soil-vc-tot}(mg/kg) = \frac{1}{\frac{1}{CL_{soil-vc-ing}} + \frac{1}{CL_{soil-vc-der}} + \frac{1}{CL_{soil-vc-inh}}}$$

3.5 Trichloroethylene

3.5.1 Ingestion

$$CL_{soil-tce-ing}(mg/kg) = \frac{TR \times AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1} \times \text{RBA} \times \frac{10^{-6} kg}{mg} \times \left[\begin{array}{l}\left(CAF_O(0.804) \times IFS_{res-adj}\left(28350\frac{mg}{kg}\right)\right) \\ +MAF_O(0.202) \times IFSM_{res-adj}\left(128700\frac{mg}{kg}\right)\end{array}\right]}$$

Where:

CAF_O = CAF_O from Section 2.5.1

MAF_O = MAF_O from Section 2.5.1

$IFS_{res\text{-}adj}$ = $IFS_{res\text{-}adj}$ from Section 3.2.1

$IFSM_{res\text{-}adj}$ = $IFSM_{res\text{-}adj}$ from Section 3.3.1

3.5.2 Dermal

$$CL_{soil-tce-der}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{ress}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{\left(\frac{CSF_0\left(\frac{mg}{kg \cdot day}\right)^{-1}}{GIABS}\right) \times \frac{10^{-6} kg}{mg}\left[\begin{array}{l}\left(CAF_O(0.804) \times DFS_{res-adj}\left(79758\frac{mg}{kg}\right) \times ABS_d\right) \\ +\left(MAF_O(0.202) \times DFSM_{res-adj}\left(330372\frac{mg}{kg}\right) \times ABS_d\right)\end{array}\right]}$$

Where:

$DFS_{res\text{-}adj}$ = $DFS_{res\text{-}adj}$ from Section 3.2.2

$DFSM_{res\text{-}adj}$ = $DFSM_{res\text{-}adj}$ from Section 3.3.2

3.5.3 Inhalation

$$CL_{water-tce-inh}\left(\frac{\mu g}{L}\right) = \frac{TR \times AT_{ress}\left(\frac{365\ days}{year} \times \mathrm{LT}(70\ years)\right)}{\mathrm{IUR}\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1}{VF_S\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times \frac{1000\ \mu g}{mg} \times \frac{day}{24\ hours}}$$

$$\times \left[\begin{array}{c}\left(EF_{ress}\left(\frac{days}{year}\right) \times ED_{ress}(26\ years) \times ET_{ress}\left(\frac{24\ hours}{day}\right) \times CAF_i(0.756)\right) \\ +\left(ED_{0-2}(2\ years) \times EF_{0-2}\left(\frac{days}{year}\right) \times ET_{0-2}\left(\frac{24\ hours}{day}\right) \times MAF_i(0.244) \times 10\right) \\ +\left(ED_{2-6}(4\ years) \times EF_{2-6}\left(\frac{days}{year}\right) \times ET_{2-6}\left(\frac{24\ hours}{day}\right) \times MAF_i(0.244) \times 3\right) \\ +\left(ED_{6-16}(10\ years) \times EF_{6-16}\left(\frac{days}{year}\right) \times ET_{6-16}\left(\frac{24\ hours}{day}\right) \times MAF_i(0.244) \times 3\right) \\ +\left(ED_{16-26}(10\ years) \times EF_{16-26}\left(\frac{days}{year}\right) \times ET_{16-26}\left(\frac{24\ hours}{day}\right) \times MAF_i(0.244) \times 1\right)\end{array}\right]$$

3.5.4 Total

$$CL_{soil-tce-tot}(mg/kg) = \frac{1}{\frac{1}{CL_{soil-tce-ing}} + \frac{1}{CL_{soil-tce-der}} + \frac{1}{CL_{soil-tce-inh}}}$$

4.0 Migration to Groundwater Cleanup Levels

4.1 Soil-Water Partitioning Equation for Migration to Groundwater

The standard default attenuation factor (AF) used to determine the cleanup standards is: AF = 4. The AF may be modified on a chemical-specific basis. The standard dilution factor is DF = 3.3 (see equation below). The standard default dilution attenuation factor (DAF) used to determine the cleanup standards is: DAF (DF x AF) = 13.2. The standard default value for fractional organic carbon (foc) is 0.001 (0.1%). Exhibit C- 4 of the Soil Screening Guidance (U.S. EPA. 1996a) provides pH-specific soil-water partition coefficients (Kd) for metals. Site-specific soil pH measurements can be used to select appropriate Kd values for these metals. Where site-specific soil pH values are not available, values corresponding to a pH of 6.8 should be used. The soil-water partitioning equation is shown below:

$$CL\,(mg/kg) = C_w\left(\frac{mg}{L}\right) \times DAF \times \left[K_d\left(\frac{L}{kg}\right) + \left(\frac{\left(\theta_w\left(\frac{L_{water}}{L_{soil}}\right) + \theta_a\left(\frac{L_{air}}{L_{soil}}\right) \times H'\right)}{P_b\left(\frac{1.5kg}{L}\right)}\right)\right]$$

Where:

$$\theta_a\left(0.13\frac{L_{air}}{L_{soil}}\right) = n\left(0.43\frac{L_{water}}{L_{soil}}\right) - \theta_w\left(0.3\frac{L_{water}}{L_{soil}}\right);$$

$$n\left(0.43\frac{L_{pore}}{L_{soil}}\right) = 1 - \left(\frac{\rho_b\left(\frac{1.5kg}{L}\right)}{\rho_s\left(\frac{2.65kg}{L}\right)}\right) and$$

$$K_d\left(\frac{L}{kg}\right) = K_{oc}\left(\frac{L}{kg}\right) \times f_{oc}(0.001\ g/g)$$

5.0 Explanation of Supporting Equations and Parameters

5.1 Derivation of the Volatilization Factor

The soil-to-air volatilization factor (VF) is used to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. VF is calculated from the equation below using chemical-specific properties and either site-measured or default values for soil moisture, dry bulk density, and fraction of organic carbon in soil. The Soil Screening Guidance: User's Guide (U.S. EPA. 1996b) describes how to develop site measured values for these parameters.

The VF is only calculated for volatile organic compounds (VOCs). VOCs, for the purpose of this document, generally are chemicals with a Henry's Law constant greater than or equal to 1×10^{-5} atm-m^3/mole and a molecular weight of less than 200 g/mol. Exceptions are: Mercury (elemental); Pyrene; Dibromochloromethane; and 1,2-Dibromo-3-chloropropane.

Because of its reliance on Henry's law, the VF model applies only when the contaminant concentration in soil is at or below saturation (i.e., no free-phase contaminant is present). Soil saturation (Csat) corresponds to the contaminant concentration in soil at which the adsorptive limits of the soil particles and the solubility limits of the available soil moisture have been reached. Above this point, pure liquid-phase contaminant is expected in the soil. If the cleanup level calculated using the VF exceeds the calculated Csat value, the cleanup level is set equal to Csat in accordance with the "Soil Screening Guidance" (U.S. EPA 1996a, 1996b). The equation for the soil saturation limit is presented in section 5.4.

Chemical specific default dermal absorption values are provided in Appendix A and obtained from Supplemental Guidance for Dermal Risk Assessment," Part E of Risk Assessment Guidance for Superfund Human Health Evaluation Manual (Volume I), July 2004 (U.S. EPA. 2004). Chemicals without default dermal absorption values and considered VOC are not quantified. The rationale for this is that in the considered soil exposure scenarios, volatile organic compounds would tend to be volatilized from the soil on skin and should be accounted for via inhalation routes in the combined exposure pathway analysis. Further, a chemical must be a VOC in order to be included in the calculation of groundwater inhalation.

$$VF\left(\frac{m^3_{air}}{kg_{soil}}\right) = \frac{\frac{Q}{C_{vol}}\left(\frac{\frac{g}{m^2 \cdot s}}{\frac{kg}{m^3}}\right) \times \left(3.14 \times D_A\left(\frac{cm^2}{s}\right) \times T(s)\right)^{1/2} \times 10^{-4}\left(\frac{m^2}{cm^2}\right)}{2 \times \rho_b\left(\frac{g}{cm^3}\right) \times D_A\left(\frac{cm^2}{s}\right)}$$

Where: $\frac{Q}{C_{vol}}\left(\frac{\frac{g}{m^2 \cdot s}}{\frac{kg}{m^3}}\right) = A \times exp\left[\frac{(lnA_S(acre) - B)^2}{C}\right]$

And:

$$D_A\left(\frac{cm^2}{s}\right) = \frac{\left[\frac{\left(\theta_a\left(\frac{L_{air}}{L_{soil}}\right)^{\frac{10}{3}} \times D_{ia}\left(\frac{cm^2}{s}\right) \times H' + \theta_w\left(0.15\frac{L_{water}}{L_{soil}}\right)^{\frac{10}{3}} \times D_{iw}\left(\frac{cm^2}{s}\right)\right)}{n^2\left(\frac{L_{pore}}{L_{soil}}\right)}\right]}{\rho_b\left(1.5\frac{g}{cm^3}\right) \times K_d\left(\frac{cm^3}{g}\right) + \theta_w\left(0.15\frac{L_{water}}{L_{soil}}\right) + \theta_a\left(\frac{L_{air}}{L_{soil}}\right) \times H'}$$

5.2 Selection of Compounds for Dermal Absorption

The single soil cleanup level for each climate zone accounts for the inhalation, ingestion and dermal contact pathways. For those contaminants that are unlikely to undergo significant dermal absorption, the final cleanup level will only reflect the soil ingestion and inhalation pathways.

Dermal absorption of contaminants in soil is calculated based on the Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment (EPA, 2004). Where specific absorption factors were not available for an organic compound and it is not considered a volatile, an absorption fraction of 0.10 is applied. It is generally accepted that volatile compounds evaporate from skin before significant absorption occurs and are addressed through the inhalation exposure pathway.

5.3 Particulate Emission Factor (PEF)

Inhalation of contaminants adsorbed to respirable particles (PM10) was assessed using a default PEF equal to 1.36 x 10^9 m^3/kg. This equation relates the contaminant concentration in soil with the concentration of respirable particles in the air due to fugitive dust emissions from contaminated soils. The generic PEF was derived using default values that correspond to a receptor point concentration of approximately 0.76 $\mu g/m^3$. The relationship is derived by Cowherd et al (1985) for a rapid assessment procedure applicable to a typical hazardous waste site, where the surface contamination provides a relatively continuous and constant potential for emission over an extended period of time (e.g., years). This represents an annual average emission rate based on wind erosion that should be compared with chronic health criteria; it is not appropriate for evaluating the potential for more acute exposures. Definitions of the input variables are in the Standard Defaults Table 7 in Appendix B.

With the exception of specific heavy metals, the PEF does not appear to significantly affect most soil cleanup levels. The equation forms the basis for deriving a generic PEF for the inhalation pathway. For more details regarding specific parameters used in the PEF model, refer to Soil Screening Guidance: Technical Background Document (U.S. EPA. 1996a). The use of alternate values on a specific site should be justified and presented in an Administrative Record if considered in Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedy selection.

Note: the generic PEF evaluates wind-borne emissions and does not consider dust emissions from traffic or other forms of mechanical disturbance that could lead to greater emissions than assumed here.

$$PEF_w\left(\frac{m^3_{air}}{kg_{soil}}\right) = \frac{Q}{C_w}\left(\frac{\frac{g}{m^2 \cdot s}}{\frac{kg}{m^3}}\right) \times \frac{3{,}600\frac{s}{hour}}{0.036 \times (1-V) \times \left(\frac{U_m\left(\frac{m}{s}\right)}{U_t\left(\frac{m}{s}\right)}\right)^3 \times F(X)}$$

Where:

$$\frac{Q}{C_w} = A \times exp\left[\frac{(lnA_s(acre)-B)^2}{C}\right]$$

5.4 Derivation of the Soil Saturation Limit (C_{sat})

The soil saturation concentration, Csat, corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the soil contaminant may be present in free phase (i.e., nonaqueous phase liquids (NAPLs) for contaminants that are liquid at ambient soil temperatures and pure solid phases for compounds that are solid at ambient soil temperatures). Csat is not calculated for chemicals that are solid at ambient soil temperatures. The following decision criteria was established from the Soil Screening Guidance User's Guide, Table C-3: if melting point is less than 20 °C, chemical is a liquid; if melting point is above 20 °C, chemical is solid (U.S. EPA. 1996b).

The equation below is used to calculate C_{sat}; for each volatile contaminant. As an update to RAGS HHEM, Part B (U.S. EPA. 1991a), this equation takes into account the amount of contaminant that is in the vapor phase in soil in addition to the amount dissolved in the soil's pore water and sorbed to soil particles.

Chemical-specific C_{sat} concentrations must be compared with each VF-based cleanup level (CL) because a basic principle of the volatilization model is not applicable when free-phase contaminants are present. How these cases are handled depends on whether the contaminant is liquid or solid at ambient temperatures. Liquid contaminants that have a VF-based CL that exceeds the C_{sat} concentration are set equal to $C_{sat;}$ whereas for solids (e.g., PAHs), soil cleanup decisions are based on the appropriate CLs for other pathways of concern at the site (e.g., ingestion).

$$C_{sat} = \frac{S\left(\frac{mg}{L}\right)}{\rho_b\left(\frac{kg}{L}\right)} \times \left(K_d\left(\frac{L}{kg}\right) \times \rho_b\left(\frac{kg}{L}\right) + \theta_w\left(\frac{L_{water}}{L_{soil}}\right) + H' \times \theta_a\left(\frac{L_{air}}{L_{soil}}\right) \right)$$

Where:

$$K_d = K_{oc}\left(\frac{L}{kg}\right) \times f_{oc}\left(0.001\frac{g}{g}\right)$$

$$\theta_a\left(\frac{L_{air}}{L_{soil}}\right) = n\left(\frac{L_{pore}}{L_{soil}}\right) - \theta_w\left(\frac{L_{water}}{L_{soil}}\right) \text{ and } n = 1 - \left(\frac{\rho_b\left(\frac{kg}{L}\right)}{\rho_s\left(\frac{kg}{L}\right)}\right)$$

5.5 Derivation of Dilution Factor

The DEC sets a default dilution factor of 3.3 generated by the following equation:

$$Dilution\ Factor\ (DF) = 1 + \frac{K\left(876\frac{m}{year}\right) \times i\left(0.002\frac{m}{m}\right) \times d(5.5m)}{I\left(0.13\frac{m}{year}\right) \times L(32m)}$$

Where d, the mixing zone, is calculated as follows:

$$d(m) = (0.0112 \times L(32m)^2)^{0.5} + d_a(10m) \times \left[1 - exp\left(\frac{-L(32m) \times I\left(0.13\frac{m}{year}\right)}{K\left(876\frac{m}{year}\right) \times i\left(0.002\frac{m}{m}\right) \times d_a(10m)}\right)\right]$$

5.6 Groundwater

5.6.1 B

B is the dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis.

$$B(unitless) = \frac{K_P\left(\frac{cm}{hour}\right)\sqrt{MW\left(\frac{g}{mol}\right)}}{2.6}$$

5.6.2 τ_{event}

τevent is the lag time per event

$$\tau_{event}\left(\frac{hours}{event}\right) = \frac{1}{6 \times 10^{(0.2 - 0.0056 \times MW)}}$$

5.6.3 t*

t* is the time to reach steady state.

$$IF\ B \leq 0.6, then\ t^*(hours) = 2.4 \times \tau_{event}\left(\frac{hours}{event}\right)$$

$$IF\ B > 0.6, then\ t^*(hours) = 6 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(b - \sqrt{b^2 - c^2}\right)$$

Where

$$b = \frac{2 \times (1 + B)^2}{\pi} - c$$

And $$c = \frac{1+3B+3B^2}{3(1+B)}$$

6.0 Petroleum Fraction Equations

Cleanup levels for the petroleum fractions presented for soil in Table B2 of 18 AAC 75.340, and for groundwater in Table C of 18 AAC 75.345, are calculated using the following set of equations. These equations were developed using the 1996 EPA Soil Screening Guidance, and remain unchanged from the last update of these cleanup level calculation procedures in June of 2008. Therefore, they do not incorporate the exposure parameters, toxicity values and assumptions of the RSL equations for non-petroleum compounds that are presented in the preceding sections of these procedures. DEC expects to update the equations for calculating the petroleum cleanup criteria as part of a future regulatory update. For chemical specific parameters for the petroleum fractions, refer to Table 1 in Section 6.9.

6.1 Groundwater Cleanup Levels for Petroleum Contaminants

Previously referred to as **Equation 15.**

$$\text{Cleanup Level (mg/L)} = \frac{\text{THQ} \times \text{RfD}_o \times \text{BW} \times \text{AT} \times 365\ \text{d/yr}}{\text{IR} \times \text{EF} \times \text{ED} \times \text{A}}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
BW/body weight (kg)	70
AT/averaging time (yr)	30
RfD_o/oral reference dose (mg/kg-d)	Chemical-specific (See Table 1)
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
IR/ ingestion rate (L/d)	2
A/absorption factor	1

For non-carcinogens, averaging time is equal to exposure duration.

6.2 Residential Soil Cleanup Levels for Ingestion of Petroleum Fractions

Previously referred to as **Equation 16.**

$$\text{Cleanup Level (mg/kg)} = \frac{\text{THQ x BW x AT x 365 d/yr}}{1/RfD_o x 10^{-6}\ \text{kg/mg x EF x ED x IR}}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
BW/body weight (kg)	15
AT/averaging time (yr)	6[a]
RfD_o/oral reference dose (mg/kg-d)	Chemical-specific (See Table 1)
EF/exposure frequency (d/yr)	Arctic Zone = 200 d/yr Under 40 Inch Zone = 270 d/yr Over 40 Inch Zone = 330 d/yr
ED/exposure duration (yr)	6
IR/soil ingestion rate (mg/d)	200

[a] For non-carcinogens, averaging time is equal to exposure duration. Cleanup levels are calculated for 6-year childhood exposure.

6.3 Residential Soil Cleanup Levels for Direct Inhalation of Petroleum Fractions

Previously referred to as **Equation 17.**

$$\text{Cleanup Level (mg/kg)} = \frac{\text{THQ x AT x 365 d/yr}}{\text{EF x ED x [(1/RfC) x (1/VF)]}}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
AT/averaging time (yr)	30
EF/exposure frequency (d/yr)	Arctic Zone = 200 d/yr Under 40 Inch Zone = 270 d/yr Over 40 Inch Zone = 330 d/yr
ED/exposure duration (yr)	30
RfC/inhalation reference concentration (mg/m^3)	Chemical-specific (See Table 1)
VF/soil-to-air volatilization factor (m^3/kg)	Chemical-specific (See Equation 18)

6.4 Derivation of the Volatilization Factor

Previously referred to as **Equation 18.**

$$VF\ (m^3/kg) = \frac{Q/C \times (3.14 \times D_A \times T)^{1/2} \times 10^{-4} m^2/cm^2}{(2 \times \rho_b \times D_A)}$$

where

$$D_A = \frac{[(\theta_a^{10/3} D_i H' + \theta_w^{10/3} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a H'}$$

Parameter/Definition (units)	Default	
VF/volatilization factor (m^3/kg)	---	
Q/C/inverse of the mean conc. at the center of a 0.5 acre square source (g/m^2-s per kg/m^3)	Arctic Zone	=101.5958
	Under 40 Inch Zone	=90.80
	Over 40 Inch Zone	=82.72
T/exposure interval (s)	8.2×10^8	
ρ_b/dry soil bulk density (g/cm^3)	1.5	
ρ_s/soil particle density (g/cm^3)	2.65	
n/total soil porosity (L_{pore}/L_{soil})	0.43 or 1 - (ρ_b/ρ_s)	
θ_w/water-filled soil porosity (L_{water}/L_{soil})	0.15 or $w\rho_b$	
θ_a/air-filled soil porosity (L_{air}/L_{soil})	0.28 or n - $w\rho_b$	
D_i/diffusivity in air (cm^2/s)	Chemical-specific (See Table 1)	
H'/ dimensionless Henry's law constant	Chemical-specific (See Table 1)	
w/average soil moisture content $kg_{water}/kg_{soil\text{-}dry}$	0.1 (10%)	
D_w/diffusivity in water (cm^2/s)	Chemical-specific (See Table 1)	
K_d/soil-water partition coefficient (cm^3/g)	K_{oc} x f_{oc} (organics)	
K_{oc}/organic carbon partition coefficient (cm^3/g)	Chemical-specific (See Table 1)	
f_{oc}/organic carbon content of soil (g/g)	0.001 (0.1%)	

6.5 Derivation of the Soil Saturation Limit

Previously referred to as **Equation 19.** Note: The Soil Saturation Limit will be used as an upper limit for petroleum for the Inhalation Pathway Calculations

$$C_{sat}\ (mg/kg) = \frac{S}{\rho_b}\ (K_d\ \rho_b + \theta_w + H'\theta_a)$$

Parameter/Definition (units)	Default
C_{sat}/soil saturation concentration (mg/kg)	---
S/solubility in water (mg/L-water)	Chemical-specific (See Table 1)
ρ_b/dry soil bulk density (kg/L)	1.5
ρ_s/soil particle density (kg/L)	2.65
n/total soil porosity (L_{pore}/L_{soil})	0.434 or 1 - (ρ_b / ρ_s)
θ_w/water-filled soil porosity (L_{water}/L_{soil})	0.15 or wρ_b
θ_a/air-filled soil porosity (L_{air}/L_{soil})	0.284 or n - wρ_b
K_d/soil-water partition coefficient (L/kg)	K_{oc} x f_{oc}
K_{oc}/soil organic carbon/water partition coefficient (L/kg)	Chemical-specific (See Table 1)
f_{oc}/fraction organic carbon of soil (g/g)	0.001 (0.1%)
w/average soil moisture content $kg_{water}/kg_{soil\text{-}dry}$	0.1 (10%)
H'/Henry's law constant (unitless)	Chemical-specific (See Table 1)

6.6 Soil-Water Partitioning Equation for Migration to Groundwater for Petroleum Fractions

Previously referred to as **Equation 20.**

$$\text{Soil cleanup level (mg/kg)} = C_w\ \{(K_{oc}\ f_{oc})\ +\ (\ (\theta_w + \theta_a H')/\ \rho_b\ )\}$$

Parameter/Definition (units)	Default
C_w/target soil leachate concentration (mg/L)	Groundwater Cleanup Level x (10 + DF), 10 is attenuation factor
K_{oc}/soil organic carbon/water partition coefficient (L/kg)	Chemical-specific (See Table 1)
f_{oc}/fraction organic carbon in soil (g/g)	0.001 (0.1%)
ρ_b/dry soil bulk density (kg/L)	1.5
ρ_s/soil particle density (kg/L)	2.65
n/total soil porosity (L_{pore}/L_{soil})	0.434 or (1 - ρ_b/ρ_s)
θ_w/water-filled soil porosity (L_{water}/L_{soil})	0.3 (30%) or wρ_b
θ_a/air-filled soil porosity (L_{air}/L_{soil})	0.13 or n -wρ_b
w/average soil moisture content $kg_{water}/kg_{soil\text{-}dry}$	0.2 (20%)
H'/Henry's law constant (unitless)	Chemical Specific (See Table 1)

6.7 Derivation of Dilution Factor

Previously referred to as **Equation 21.**

$DF = 1 + (Kid / IL)$	
Parameter/Definition (units)	Default
DF/dilution factor (unitless)	---
K/aquifer hydraulic conductivity (m/yr)	876 m/yr
i/hydraulic gradient (m/m)	0.002 m/m
d/mixing zone depth (m)	(See Equation 22 below)
I/infiltration rate (m/yr) (calculated as 1/5 * (mean plus one standard deviation of yearly rainfall))	Over 40 Inch Zone =0.6 m/yr Under 40 Inch Zone =0.13 m/yr
L/source length parallel to groundwater flow (m)	32 m
The standard default dilution factors used to determine the cleanup standards are DF = 1.9 for the Over 40 Inch Zone; and DF = 3.3 for the Under 40 Inch Zone.	

6.8 Estimation of Mixing Zone Depth

Previously referred to as **Equation 22.**

$d = (0.0112L^2)^{0.5} + d_a\{1 - \exp[(-LI)/(Kid_a)]\}$	
Parameter/Definition (units)	Default
d/mixing zone depth (m)	---
L/source length parallel to groundwater flow (m)	32 m
I/infiltration rate (m/yr) (calculated as 1/5 * (mean plus one standard deviation of yearly rainfall))	Over 40 Inch Zone =0.6 m/yr Under 40 Inch Zone =0.13 m/yr
K/aquifer hydraulic conductivity (m/yr)	876 m/yr
i/hydraulic gradient (m/m)	0.002
d_a/aquifer thickness (m)	10 m
The standard default mixing zone depths used to determine the cleanup standards are: d = 10.0 for the Over 40 Inch Zone; and d = 5.5 for the Under 40 Inch Zone.	

6.9 Chemical Specific Parameters

Table 1- Chemical Specific Parameters for Petroleum Hydrocarbon Fractions

HENRY'S LAW CONSTANT, H' (unitless)

aromatics $\log_{10} H = [-0.23][EC] + 1.7$

aliphatics $\log_{10} H = [0.02][EC] + 1.6$

ORGANIC CARBON PARTITION COEFFICIENT, Koc (ml/g)

aromatics $\log_{10} Koc = [0.10][EC] + 2.3$

Aliphatics $\log_{10} Koc = [0.45][EC] + 0.43$

Hydrocarbon Range	Equivalent Carbon Number (EC)	Oral Reference Dose (mg/kg/day)	Reference Concentration (mg/m^3)	H' (unitless)	Koc	Diffusivity in Air	Diffusivity in Water
C_6-C_{10} Aliphatics	8	5	18.4	5.75 E+1	1.07 E+4	1 E-1	1 E-5
C_6-C_{10} Aromatics	8	0.2	0.4	7.24 E-1	1.26 E+3	1 E-1	1 E-5
C_{10}-C_{25} Aliphatics	14	0.1	1	7.59 E+1	5.37 E+6	1 E-1	1 E-5
C_{10}-C_{25} Aromatics	14	0.04	0.2	3.02 E-2	5.01 E+3	1 E-1	1 E-5
C_{25}-C_{36} Aliphatics	30.5	2	n/a				
C_{25}-C_{36} Aromatics	30.5	0.03	n/a	4.86 E-6	2.24 E+5	1 E-1	1 E-5

*Note that no values are recommended for the C_{25}-C_{36} aliphatic fraction, as these compounds are essentially immobile in the environment.

6.10 Total Gasoline, Diesel, and Residual Range Organics (GRO, DRO, and RRO) Versus Aromatic/Aliphatic Fractions

Table B2 soil cleanup levels for petroleum hydrocarbons (GRO, DRO, and RRO) are based on Methods AK 101, 102, and 103. The Table B2 GRO, DRO, and RRO levels were derived based on assumed default percentages of aromatic and aliphatic fractions within each carbon range. The Table B2 aliphatic/aromatic fractional cleanup levels were transformed into the GRO, DRO, and RRO levels by dividing the aromatic or aliphatic cleanup level by a corresponding aromatic or aliphatic default percentage.

DEC selected the default compositions of GRO, DRO, and RRO shown in Table 2.

Table 2: Petroleum Hydrocarbon Default Compositions

CARBON RANGE	PERCENT ALIPHATIC*	PERCENT AROMATIC*
GRO - C_6 - C_{10}	70	50
DRO - C_{10} - C_{25}	80	40
RRO - C_{25} - C_{36}	90	30

*Note - Because fuel constituents vary considerably, the default composition of the percent aliphatic and percent aromatics was set at 120% of the total.

For example, the C10-C25 DRO cleanup levels in Table B2 were calculated by dividing the corresponding C10-C25 aliphatic level by 0.80 and also dividing the corresponding C10-C25 aromatic level by 0.40. The lowest result of these two calculations became the method two C10-C25 DRO cleanup level (TPHCWG, 1997).

7.0 Calculating Cleanup Levels under Method Three

Table B1 Contaminants

Alternative residential soil cleanup levels may be developed under method three (18 AAC 75.340(e)) utilizing site-specific data for the soil migration to groundwater pathway. Site-specific parameters that may be modified for Table B1 compounds are listed in Table 3. Equations for the Table B1 contaminants are found in Sections 2.0 through 4.0.

Table 3 – Site-Specific Parameters for Table B1 Compounds		
Parameters[1]	Definition (units)	Default Value
f_{oc}	Fractional organic carbon (g/g)	0.001 (1%)
ρ_b	dry soil bulk density (kg/L)	1.5
θw	water-filled soil porosity (L_{water}/L_{soil})	0.15
ρ_s	Soil particle density (kg/L)	2.65
K	Aquifer hydraulic conductivity (m/year)	876
L	Source length parallel to ground water flow (m)	32
d_a	Aquifer thickness (m)	10
I	Hydraulic gradient (m/m)	0.002
I	Infiltration rate (m/yr)	0.13
AF	Attenuation Factor (unitless)	4

Table B2 Petroleum Fractions

Alternative residential soil cleanup levels may be developed under method three (18 AAC 75.340(e)) utilizing site-specific data for the soil migration to groundwater pathway. Site-specific parameters that may be modified for Table B2 petroleum fractions are listed in Table 4. Equations for the petroleum fractions are in Section 6.0.

Table 4 – Site-Specific Parameters for Petroleum Fraction Equations		
Parameters[1]	Definition (units)	Default Value
f_{oc}	Fractional organic carbon (g/g)	0.001 (1%)
ρ_b	dry soil bulk density (kg/L)	1.5
n	total soil porosity (L_{pore}/L_{soil})	0.434 or (1 - ρ_b/ρ_s)
θw	water-filled soil porosity (L_{water}/L_{soil})	0.15 or $w\rho_b$
0a	air-filled soil porosity (L_{air}/L_{soil})	0.284 or n - $w\rho_b$
w	average soil moisture content kg_{water}/kg_{soil}-dry	0.1 (10%)
K	Aquifer hydraulic conductivity (m/yr)	876 m/yr
i	Hydraulic gradient (m/m)	0.002 m/m
d	Mixing zone depth (m)	See Mixing Zone Depth Equation 22
I	Infiltration rate (m/yr)	>40 inch zone =0.6m/yr <40 inch zone = 0.13 m/yr
L	Source length parallel to groundwater flow (m)	32 m
d_a	Aquifer thickness (m)	10 m

For either Table B1 or B2 contaminants, if a site-specific dry soil bulk density will be used, then the total porosity, air-filled porosity, and water-filled porosity must be calculated using the appropriate equation the respective contaminant. Note that the air-filled soil porosity is the portion of the total porosity of soil containing air. This value is calculated by subtracting the water-filled porosity from the total soil porosity. If a site-specific total soil porosity or water-filled soil porosity is determined for a site, then the air-filled soil porosity should be reviewed to ensure that the sum of the air-filled and water-filled soil porosities equals the total soil porosity.

A standard default mixing zone depth has been adopted by the department for application to Table B1 contaminants. This value cannot be modified. However, for Table B2 petroleum fractions, this value can be modified using site-specific information (see Table 4).

Commercial/Industrial Land Use Scenario

Alternative soil cleanup levels may also be proposed for commercial/industrial exposure scenarios under method three. However, sites where a commercial/industrial exposure scenario is proposed requires an institutional control to ensure that the land use remains commercial industrial in perpetuity, unless a future cleanup action is performed that brings the site into compliance with a residential exposure scenario. Values for parameters that are applied for this scenario are shown in Table 5.

Table 5- Commercial/Industrial Exposure Parameters

Parameters	Definition (units)	Value
AT	averaging time for carcinogens (years)	70 (unchanged from residential)
AT	averaging time for non-carcinogens (years)	25
BW	body weight (kg)	80
ED	exposure duration (years)	25
EF	exposure frequency (days/years)	250 (under 40 inch and over 40 inch zones) 200 (arctic zone)
IRsoil	soil ingestion rate (mg/day)	100 (outdoor worker) 50 (indoor worker)
SA	Surface Area	3527 cm^2
AF	Adherence Factors	0.12 mg/cm^2

For additional guidance on the equations for and calculation of commercial/industrial cleanup levels, reference the EPA Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (U.S. EPA. 2002).

8.0 References

ADEC (Alaska Department of Environmental Conservation). 2018. Risk Assessment Procedures Manual.

Calabrese, Edward J., Ramon Barnes, Edward J. Stanek III, Harris Pastides, Charles E. Gilbert, Peter Veneman, Xioaru Wang, Alexandra Lasztity, Paul T. Kostecki, How much soil do young children ingest: An epidemiologic study, Regulatory Toxicology and Pharmacology, Volume 10, Issue 2, October 1989, Pages 123-137, ISSN 0273-2300, 10.1016/0273-2300(89)90019-6. (http://www.sciencedirect.com/science/article/pii/0273230089900196)

Cowherd, C., G.E. Muleski, P.J. Englehart, and D.A. Gillette. 1985. Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites. Kansas City, MO. Midwest Research Institute. PB85-192219.

Davis, Scott, et al. "Quantitative estimates of soil ingestion in normal children between the ages of 2 and 7 years: population-based estimates using aluminum, silicon, and titanium as soil tracer elements." *Archives of Environmental Health: An International Journal* 45.2 (1990): 112-122.

Harding Lawson Associates. 1995. Final Report Cleanup Level Matrix for Hazardous Substances in Soil Various Sites, Alaska.

TPHCWG (Total Petroleum Hydrocarbon Criteria Working Group) 1997. Vol. 1-5, Amherst Scientific Publishers. ISBN 1-884-940-13-7.

U.S. EPA (Environmental Protection Agency). 1987. Processes, Coefficients, and Models for Simulation Toxic Organics and Heavy Metals in Surface Waters. EPA/600/3-87/015. Office of Research and Development, Athens, GA.

U.S. EPA. 1989. Risk assessment Guidance for Superfund. Volume I: Human health evaluation manual (Part A). Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002.

U.S. EPA. 1991a. Human health evaluation manual, supplemental guidance: "Standard default exposure factors". OSWER Directive 9285.6-03.

U.S. EPA. 1991b. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals). Office of Emergency and Remedial Response. EPA/540/R-92/003. December 1991

U.S. EPA. 1996a. Soil Screening Guidance: Technical Background Document. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-17A
http://www.epa.gov/superfund/health/conmedia/soil/introtbd.htm

U.S. EPA. 1996b. Soil Screening Guidance: User's Guide. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-23
http://www.epa.gov/superfund/health/conmedia/soil/index.htm#user

U.S. EPA. 1997a. Exposure Factors Handbook. Office of Research and Development, Washington, DC. EPA/600/P-95/002Fa.

U.S. EPA. 2000. Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds. Part I: Estimating Exposure to Dioxin-Like Compounds. Volume 3--Properties, Environmental Levels, and Background Exposures. Draft Final Report. EPA/600/P- 00/001. Office of Research and Development, Washington, DC. September.

U.S. EPA. 2001. WATER9. Version 1.0.0. Office of Air Quality Planning and Standards, Research Triangle Park, NC. Web site at: http://www.epa.gov/ttn/chief/software/water/index.html

U.S. EPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. December 2002.
http://www.epa.gov/superfund/health/conmedia/soil/index.htm

U.S. EPA. 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. OSWER 9285.7-02EP.July 2004. Document and website:
http://www.epa.gov/oswer/riskassessment/ragse/index.htm

U.S. EPA. 2009. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment) Final. OSWER 9285.7-82. January 2009. Document, memo and website:
http://www.epa.gov/oswer/riskassessment/ragsf/index.htm

U.S. EPA 2012. Regional Screening Table – User's Guide. Available at:
http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm.

Van Wijnen, J. H., P. Clausing, and B. Brunekreef. Estimated soil ingestion by children. Environmental research 51.2 (1990): 147-162

Appendix A – Toxicity and Chemical Specific Parameters for Non-Petroleum Organic and Inorganic Contaminants

Symbol	Definition
GIABS	Fraction of contaminant absorbed in gastrointestinal tract (unitless) Note: if the GIABS is >50% then it is set to 100% for the calculation of dermal toxicity values.
ABS	Fraction of contaminant absorbed dermally from soil (unitless)
RBA	Relative bioavailability factor
Ingestion SF	Chronic Oral Slope Factor (mg/kg-day)-1
IUR	Chronic Inhalation Unit Risk (µg/m3)-1
RfD	Chronic Oral Reference Dose (mg/kg-day)
RfC	Chronic Inhalation Reference Concentration (mg/m3)
D_a	Diffusivity in air (cm2/hour)
D_w	Diffusivity in water (cm2/hour)
S	Water Solubility Limit (mg/L)
K_d	Soil-water partition coefficient (L/kg) (Koc*foc)
K_{oc}	Soil organic carbon/water partition coefficient (L/kg)
H'	Dimensionless Henry's Law Constant (unitless)
MW	Molecular Weight (g/mol)
FA	Systemically available fraction
K_p	Dermal permeability coefficient in water (cm/hour)
MP	Melting Point (°C)

Table 6 Chemical Toxicity Parameters

CAS Number[1]	Compound	GIABS	ABS	RBA	Ingestion SF (mg/kg day)$^{-1}$	Ref[2]	Inhalation Unit Risk ($\mu g/m^3$)$^{-1}$	Ref[2]	Chronic RfD (mg/kg day)	Ref[2]	Chronic RfC (mg/m^3)	Ref[2]
83-32-9	Acenaphthene	1	0.13	1	-		-		0.06	I	-	
208-96-8	Acenaphthylene[3]	1	0.13	1	-		-		0.03	S	-	
67-64-1	Acetone	1	-	1	-		-		0.9	I	30.880981595092	A
309-00-2	Aldrin	1	-	1	17	I	0.0049	I	0.00003	I	-	
14797-73-0	Perchlorate and Perchlorate Salts	1	-	1	-		-		0.0007	I	-	
120-12-7	Anthracene	1	0.13	1	-				0.3	I	-	
7440-36-0	Antimony (metallic)	0.15	-	1	-		-		0.0004	I	-	
7440-38-2	Arsenic, Inorganic	1	0.03	0.6	1.5	I	0.0043	I	0.0003	I	0.000015	C
7440-39-3	Barium	0.07	-	1	-		-		0.2	I	0.0005	H
56-55-3	Benz[a]anthracene[3]	1	0.13	1	0.1	S	0.00006	S	-		-	
100-52-7	Benzaldehyde	1	-	1	0.004	P	-		0.1	I	-	
71-43-2	Benzene	1	-	1	0.055	I	7.8×10^{-6}	I	0.004	I	0.03	I
50-32-8	Benzo[a]pyrene	1	0.13	1	1	I	0.0006	I	0.0003	I	0.000002	I
205-99-2	Benzo[b]fluoranthene[3]	1	0.13	1	0.1	S	0.00006	S	-		-	
191-24-2	Benzo[g,h,i]perylene[4]	1	0.13	1	-		-		0.03	S	-	
207-08-9	Benzo[k]fluoranthene[3]	1	0.13	1	0.01	S	0.0006	S	-		-	
65-85-0	Benzoic Acid	1	0.1	1	-		-		4	I	-	
100-51-6	Benzyl Alcohol	1	0.1	1			-		0.1	P	-	
7440-41-7	Beryllium and compounds	0.007	-	1	-		0.0024	I	0.002	I	0.00002	I
111-44-4	Bis(2-chloroethyl)ether	1	-	1	1.1	I	0.00033	I				
117-81-7	Bis(2-ethylhexyl)phthalate	1	0.1	1	0.014	I	2.4×10^{-6}	C	0.02	I	-	
108-86-1	Bromobenzene	1	-	1			-		0.008	I	0.06	I
75-27-4	Bromodichloromethane	1	-	1	0.062	I	0.000037	C	0.02	I	-	
75-25-2	Bromoform	1	-	1	0.0079	I	1.1×10^{-6}	I	0.02	I	-	
74-83-9	Bromomethane	1	-	1	-		-		0.0014	I	0.005	I
106-99-0	Butadiene, 1,3	1	-	1	3.4	C	0.00003	I	-		0.002	I
71-36-3	Butanol, N-	1	-	1	-		-		0.1	I	-	
85-68-7	Butyl Benzyl Phthalate	1	0.1	1	0.0019	P	-		0.2	I	-	
104-51-8	Butylbenzene, n-	1	-	1	-		-		0.05	P	-	
135-98-8	Butylbenzene, sec-	1	-	1	-		-		0.1	X	-	
98-06-6	Butylbenzene, tert-	1	-	1	-		-		0.1	X	-	
7440-43-9	Cadmium (Diet)	0.025	0.001	1	-		0.0018	I	0.001	I	1.0×10^{-5}	A
7440-43-9	Cadmium (Water)				-		0.0018	I	0.0005	I	1.0×10^{-5}	A
75-15-0	Carbon Disulfide	1	-	1	-		-		0.1	I	0.7	I
56-23-5	Carbon Tetrachloride	1	-	1	0.07	I	6.0×10^{-6}	I	0.004	I	0.1	I
12789-03-6	Chlordane	1	0.04	1	0.35	I	0.0001	I	0.0005	I	0.0007	I
143-50-0	Chlordecone (Kepone)	1	0.1	1	10	I	0.0046	C	0.0003	I	-	
106-47-8	Chloroaniline, p-	1	0.1	1	0.2	P	-		0.004	I	-	
108-90-7	Chlorobenzene	1	-	1	-		-		0.02	I	0.05	P
67-66-3	Chloroform	1	-	1	0.031	C	2.3×10^{-5}	I	0.01	I	0.09765235173824	A
74-87-3	Chloromethane	1	-	1	-		-		-		0.09	I

CAS Number[1]	Compound	GIABS	ABS	RBA	Ingestion SF (mg/kg day)$^{-1}$	Ref[2]	Inhalation Unit Risk (µg/m^3)$^{-1}$	Ref[2]	Chronic RfD (mg/kg day)	Ref[2]	Chronic RfC (mg/m^3)	Ref[2]
91-58-7	Chloronaphthalene, Beta-	1	0.13	1	-		-		0.08	I	-	
95-57-8	Chlorophenol, 2-	1	-	1	-		-		0.005	I	-	
16065-83-1	Chromium(III), Insoluble Salts	0.013	-	1	-		-		1.5	I	-	
18540-29-9	Chromium(VI)	0.025	-	1	0.5	C	0.084	S	0.003	I	0.0001	I
218-01-9	Chrysene[3]	1	0.13	1	0.001	S	0.00000006	S	-		-	
7440-50-8	Copper	1	-	1	-		-		0.04	H	-	
108-39-4	Cresol, m-	1	0.1	1	-		-		0.05	I	0.6	C
95-48-7	Cresol, o-	1	0.1	1	-		-		0.05	I	0.6	C
106-44-5	Cresol, p-	1	0.1	1	-		-		0.1	A	0.6	C
98-82-8	Cumene	1	-	1	-		-		0.1	I	0.4	I
57-12-5	Cyanide (CN-)[4]	1	-	1	-		-		0.0006	I	0.0008	S
110-82-7	Cyclohexane	1	-	1	-		-		-		6	I
72-54-8	DDD	1	0.1	1	0.24	I	0.000069	C	0.00003	X	-	
72-55-9	DDE, p,p'-	1	-	1	0.34	I	0.000097	C	0.0003	X	-	
50-29-3	DDT	1	0.03	1	0.34	I	0.000097	I	0.0005	I	-	
53-70-3	Dibenz[a,h]anthracene[3]	1	0.13	1	1	S	0.0006	S	-		-	
132-64-9	Dibenzofuran	1	0.03	1	-		-		0.001	X	-	
124-48-1	Dibromochloromethane	1	-	1	0.084	I	-		0.02	I	-	
106-93-4	Dibromoethane, 1,2-	1	-	1	2	I	0.0006	I	0.009	I	0.009	I
74-95-3	Dibromomethane (Methylene Bromide)	1	-	1	-		-		-		0.004	X
84-74-2	Dibutyl Phthalate	1	0.1	1	-		-		0.1	I	-	
95-50-1	Dichlorobenzene, 1,2-	1	-	1	-		-		0.09	I	0.2	H
541-73-1	Dichlorobenzene, 1,3-[5]	1	-	1	-		-		0.09	S	0.2	S
106-46-7	Dichlorobenzene, 1,4-	1	-	1	0.0054	C	0.000011	C	0.07	A	0.8	I
91-94-1	Dichlorobenzidine, 3,3'-	1	0.1	1	0.45	I	0.00034	C	-		-	
75-71-8	Dichlorodifluoromethane	1	-	1	-		-		0.2	I	0.1	X
75-34-3	Dichloroethane, 1,1-	1	-	1	0.0057	C	1.6×10^{-6}	C	2.00	P	-	
107-06-2	Dichloroethane, 1,2-	1	-	1	0.091	I	0.000026	I	0.006	X	0.007	P
75-35-4	Dichloroethylene, 1,1-	1	-	1	-		-		0.05	I	0.2	I
156-59-2	Dichloroethylene, 1,2-cis-	1	-	1	-		-		0.002	I	-	
156-60-5	Dichloroethylene, 1,2-trans-	1	-	1	-		-		0.02	I	-	
120-83-2	Dichlorophenol, 2,4-	1	0.1	1	-		-		0.003	I	-	
94-75-7	Dichlorophenoxy Acetic Acid, 2,4-	1	0.05	1	-		-		0.01	I	-	
78-87-5	Dichloropropane, 1,2-	1	-	1	0.037	P	0.0000037	P	0.04	P	0.004	I
542-75-6	Dichloropropene, 1,3-	1	-	1	0.1	I	4.0×10^{-6}	I	0.03	I	0.02	I
60-57-1	Dieldrin	1	0.1	1	16	I	0.0046	I	0.00005	I	-	
84-66-2	Diethyl Phthalate	1	0.1	1	-		-		0.8	I	-	
105-67-9	Dimethylphenol, 2,4-	1	0.1	1	-		-		0.02	I	-	
131-11-3	Dimethylphthalate[3]	1	0.1	1	-		-		0.8	S	-	
528-29-0	Dinitrobenzene, 1,2-	1	0.1	1	-		-		0.0001	P	-	
99-65-0	Dinitrobenzene, 1,3-	1	0.1	1	-		-		0.0001	I	-	
100-25-4	Dinitrobenzene, 1,4-	1	0.1	1	-		-		0.0001	P	-	
51-28-5	Dinitrophenol, 2,4-	1	0.1	1	-		-		0.002	I	-	
121-14-2	Dinitrotoluene, 2,4-	1	0.102	1	0.31	C	0.000089	C	0.002	I	-	

CAS Number[1]	Compound	GIABS	ABS	RBA	Ingestion SF (mg/kg day)$^{-1}$	Ref[2]	Inhalation Unit Risk ($\mu g/m^3$)$^{-1}$	Ref[2]	Chronic RfD (mg/kg day)	Ref[2]	Chronic RfC (mg/m^3)	Ref[2]
606-20-2	Dinitrotoluene, 2,6-	1	0.099	1	1.5	P	-		0.0003	X	-	
35572-78-2	Dinitrotoluene, 2-Amino-4,6-[33]	1	0.006	1	-		-		0.002	S	-	
19406-51-0	Dinitrotoluene, 4-Amino-2,6-[33]	1	0.009	1			-		0.002	S	-	
123-91-1	Dioxane, 1,4-	1	-	1	0.1	I	5×10^{-6}	I	0.03	I	0.03	I
122-39-4	Diphenylamine	1	0.1	1	-		-		0.1	O	-	
115-29-7	Endosulfan	1	-	1	-		-		0.006	I	-	
72-20-8	Endrin	1	0.1	1	-		-		0.0003	I	-	
75-00-3	Ethyl Chloride	1	-	1	-		-		-		10	I
100-41-4	Ethylbenzene	1	-	1	0.011	C	2.5×10^{-6}	C	0.1	I	1	I
107-21-1	Ethylene Glycol	1	0.1	1	-		-		2	I	0.4	C
206-44-0	Fluoranthene	1	0.13	1	-		-		0.04	I	-	
86-73-7	Fluorene	1	0.13	1	-		-		0.04	I	-	
50-00-0	Formaldehyde	1	-	1	-		0.000013	I	0.2	I	0.00982576687116	A
76-44-8	Heptachlor	1	-	1	4.5	I	0.0013	I	0.0005	I	-	
1024-57-3	Heptachlor Epoxide	1	-	1	9.1	I	0.0026	I	0.000013	I	-	
118-74-1	Hexachlorobenzene	1	-	1	1.6	I	0.00046	I	0.0008	I	-	
87-68-3	Hexachlorobutadiene	1	-	1	0.078	I	0.000022	I	0.001	P	-	
319-84-6	Hexachlorocyclohexane, Alpha-	1	0.1	1	6.3	I	0.0018	I	0.008	A	-	
319-85-7	Hexachlorocyclohexane, Beta-	1	0.1	1	1.8	I	0.00053	I	-		-	
58-89-9	Hexachlorocyclohexane, Gamma- (Lindane)	1	0.04	1	1.1	C	0.00031	C	0.0003	I	-	
77-47-4	Hexachlorocyclopentadiene	1	-	1	-		-		0.006	I	0.0002	I
67-72-1	Hexachloroethane	1	-	1	0.04	I	0.000011	C	0.0007	I	0.03	I
121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1	0.015	1	0.11	I	-		0.003	I	-	
110-54-3	Hexane, N-	1	-	1	-		-		-		0.7	I
591-78-6	Hexanone, 2-	1	-	1	-		-		0.005	I	0.03	I
302-01-2	Hydrazine	1	-	1	3	I	0.0049	I	-		0.00003	P
193-39-5	Indeno[1,2,3-cd]pyrene[3]	1	0.13	1	0.1	S	0.00006	S	-		-	
78-59-1	Isophorone	1	0.1	1	0.00095	I	-		0.2	I	2	C
67-63-0	Isopropanol	1		1	-		-		2	P	0.2	P
7439-92-1	Lead and Compounds[8]	1	-	1	-		-		-		-	
7439-95-5	Manganese, Total	0.04	-	1	-		-		0.024	S	0.00005	I
7487-94-7	Mercuric Chloride[9]	0.07	-	1	-		-		0.0003	I	0.0003	S
7439-97-6	Mercury (elemental)	1	-	1	-		-				0.0003	I
67-56-1	Methanol	1	-	1	-		-		2	I	20	I
72-43-5	Methoxychlor	1	0.1	1	-		-		0.005	I	-	
78-93-3	Methyl Ethyl Ketone (2-Butanone)	1	-	1	-		-		0.6	I	5	I
108-10-1	Methyl Isobutyl Ketone (4-methyl-2-pentanone)	1	-	1	-		-		-		3	I
22967-92-6	Methyl Mercury	1	-	1	-		-		0.0001	I	-	
1634-04-4	Methyl tert-Butyl Ether (MTBE)	1	-	1	0.0018	C	2.6×10^{-7}	C	-		3	I
75-09-2	Methylene Chloride	1	-	1	0.002	I	1×10^{-8}	I	0.006	I	0.6	I
90-12-0	Methylnaphthalene, 1-	1	0.13	1	0.029	P	-		0.07	A	-	
91-57-6	Methylnaphthalene, 2-	1	0.13	1	-		-		0.004	I	-	
91-20-3	Naphthalene	1	0.13	1	-		0.000034	C	0.02	I	0.003	I
7440-02-0	Nickel Soluble Salts	0.04	-	1	-		0.00026	C	0.02	I	0.00009	A

CAS Number[1]	Compound	GIABS	ABS	RBA	Ingestion SF (mg/kg day)$^{-1}$	Ref[2]	Inhalation Unit Risk ($\mu g/m^3$)$^{-1}$	Ref[2]	Chronic RfD (mg/kg day)	Ref[2]	Chronic RfC (mg/m^3)	Ref[2]
98-95-3	Nitrobenzene	1	-	1	-		0.00004	I	0.002	I	0.009	I
55-63-0	Nitroglycerin	1	0.1	1	0.017	P	-		0.0001	P	-	
556-88-7	Nitroguanidine	1	0.1	1	-		-		0.1	I	-	
62-75-9	Nitrosodimethylamine, N-	1	-	1	51	I	0.014	I	8×10^{-4}	P	0.00004	X
621-64-7	Nitroso-di-N-propylamine, N-	1	0.1	1	7	I	0.002	C	-		-	
86-30-6	Nitrosodiphenylamine, N-	1	0.1	1	0.0049	I	2.6×10^{-6}	C	-		-	
99-08-1	Nitrotoluene, m-	1	0.1	1	-		-		0.0001	X	-	
88-72-2	Nitrotoluene, o-	1	-	1	0.22	P	-		0.0009	P	-	
99-99-0	Nitrotoluene, p-	1	0.1	1	0.016	P	-		0.004	P	-	
2691-41-0	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	1	0.006	1	-		-		0.05	I	-	
117-84-0	Octyl Phthalate, di-N-	1	0.1	1	-		-		0.01	P	-	
87-86-5	Pentachlorophenol	1	0.25	1	0.4	I	5.1×10^{-6}	C	0.005	I	-	
78-11-5	Pentaerythritol tetranitrate (PETN)	1	0.1	1	0.004	X	-		0.002	P	-	
1763-23-1	Perfluorooctane sulfonic acid (PFOS)[10]	1	0.1	1	-		-		0.00002	W	-	
335-67-1	Perfluorooctanoic Acid (PFOA)[11]	1	0.1	1	0.07	W	-		0.00002	W	-	
85-01-8	Phenanthrene[4]	1	0.13	1	-		-		0.03	S	-	
108-95-2	Phenol	1	0.1	1	-		-		0.3	I	0.2	C
7723-14-0	Phosphorus, White	1	-	1	-		-		0.00002	I	-	
1336-36-3	Polychlorinated Biphenyls[13]	1	0.14	1	2	I	0.000571428571428	I	-		-	
103-65-1	Propyl benzene	1	-	1	-		-		0.1	X	1	X
129-00-0	Pyrene	1	0.13	1	-		-		0.03	I	-	
7782-49-2	Selenium	1	-	1	-		-		0.005	I	0.02	C
7440-22-4	Silver	0.04	-	1	-		-		0.005	I	-	
7440-24-6	Strontium, Total	1	-	1	-		-		0.6	I	-	
100-42-5	Styrene	1	-	1	-		-		0.2	I	1	I
1746-01-6	TCDD, 2,3,7,8-[12]	1	0.03	1	130000	C	38	C	7×10^{-10}	I	4×10^{-8}	C
630-20-6	Tetrachloroethane, 1,1,1,2-	1	-	1	0.026	I	7.4×10^{-5}	I	0.03	I	-	
79-34-5	Tetrachloroethane, 1,1,2,2-	1	-	1	0.2	I	0.000058	C	0.02	I	-	
127-18-4	Tetrachloroethylene	1	-	1	0.0021	I	2.6×10^{-7}	I	0.006	I	0.04	I
479-45-8	Tetryl (Trinitrophenylmethylnitramine)	1	0.00065	1	-		-		0.002	P	-	
7440-28-0	Thallium (Soluble Salts)	1	-	1	-		-		1×10^{-5}	X	-	
108-88-3	Toluene	1	-	1	-		-		0.08	I	5	I
8001-35-2	Toxaphene	1	0.1	1	1.1	I	0.00032	I	-		-	
76-13-1	Trichloro-1,2,2-trifluoroethane, 1,1,2-	1	-	1	-		-		30	I	5	P
87-61-6	Trichlorobenzene, 1,2,3-	1	-	1	-		-		0.0008	X	-	
120-82-1	Trichlorobenzene, 1,2,4-	1	-	1	0.029	P	-		0.01	I	0.002	P
71-55-6	Trichloroethane, 1,1,1-	1	-	1	-		-		2	I	5	I
79-00-5	Trichloroethane, 1,1,2-	1	-	1	0.057	I	0.000016	I	0.004	I	0.0002	X
79-01-6	Trichloroethylene	1	-	1	0.046	I	4.1×10^{-6}	I	0.0005	I	0.002	I
75-69-4	Trichlorofluoromethane	1	-	1	-		-		0.3	I	-	
95-95-4	Trichlorophenol, 2,4,5-	1	0.1	1	-		-		0.1	I	-	
88-06-2	Trichlorophenol, 2,4,6-	1	0.1	1	0.011	I	3.1×10^{-6}	I	0.001	P	-	
93-76-5	Trichlorophenoxyacetic Acid, 2,4,5-	1	0.1	1	-		-		0.01	I	-	
93-72-1	Trichlorophenoxypropionic acid, 2,4,5	1	0.1	1	-		-		0.008	I	-	

CAS Number[1]	Compound	GIABS	ABS	RBA	Ingestion SF (mg/kg day)[-1]	Ref[2]	Inhalation Unit Risk (µg/m³)[-1]	Ref[2]	Chronic RfD (mg/kg day)	Ref[2]	Chronic RfC (mg/m³)	Ref[2]
96-18-4	Trichloropropane, 1,2,3-	1	-	1	30	I	-		0.004	I	0.0003	I
95-63-6	Trimethylbenzene, 1,2,4-	1	-	1	-		-		0.01	I	0.06	I
108-67-8	Trimethylbenzene, 1,3,5-	1	-	1	-		-		0.01	I	0.06	I
688-73-3	Tri-n-butyltin	1	-	1	-		-		0.0003	A	-	
99-35-4	Trinitrobenzene, 1,3,5-	1	0.019	1	-		-		0.03	I	-	
118-96-7	Trinitrotoluene, 2,4,6-	1	0.032	1	0.03	I	-		0.0005	I	-	
7440-62-2	Vanadium and Compounds	0.026	-	1	-		-		0.00504	X	0.0001	A
108-05-4	Vinyl Acetate	1	-	1	-		-		1	H	0.2	I
75-01-4	Vinyl Chloride	1	-	1	0.72	I	4.4×10^{-6}	I	0.003	I	0.1	I
1330-20-7	Xylenes	1	-	1	-		-		0.2	I	0.1	I
7440-66-6	Zinc and Compounds	1	-	1	-		-		0.3	I	-	

[1] "CAS Number" means the Chemical Abstract Service (CAS) registry number uniquely assigned to chemicals by the American Chemical Society and recorded in the CAS Registry System.

[2] Reference source for data; I= Integrated Risk Information System; P= Provisional Peer Reviewed Toxicity Values; A= Agency for Toxic Substances and Disease Registry; C= California Environmental Protection Agency (EPA); X=Appendix Provisional Peer Reviewed Toxicity Values Screen; H=EPA's Health Effects Assessment Summary Tables; J=New Jersey; S=Surrogate Compound; W= EPA Office of Water; O=EPA's Office of Pesticide Programs

[3] Polycyclic aromatic hydrocarbons (PAH) ingestion slope factors are determined using Benzo[a]pyrene and Toxicity Equivalence Factors (TEFs) as described in the Risk Assessment Procedures Manual

[4] Pyrene is a toxicity surrogate for acenaphthylene, benzo(g,h,i)perylene, and phenanthrene

[5] Cyanide expressed as free, or physiologically available cyanide; The IRIS RfC for "Hydrogen Cyanide" is used as a surrogate for "Cyanide (CN-)"

[6] 1,2-dichlorobenzene is a toxicity surrogate for 1,3-dichlorobenzene

[7] Diethylphthalate is a toxicity surrogate for dimethylphthalate

[8] Lead cleanup levels are based on land use; for residential land use, the soil cleanup level is 400 mg/kg

[9] Elemental mercury is a toxicity surrogate for mercuric chloride

[10] Toxicity is given in EPA's Health Effects Support Document for Perfluorooctane Sulfonate (PFOS) 2016. Perfluorooctane Sulfonic Acid includes both the acid and its salt.

[11] Toxicity is given in EPA's Health Effects Support Document for Perfluorooctanoic Acid (PFOA) 2016.

[12] The cleanup level in 18 AAC 75.341(c) Table B1 is for 2,3,7,8-Terrachlorodibenzo p-Dioxin (TCDD) only; all cleanup levels for polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran congeners must be determined on a site-specific basis. For more information on this, see Section 5.2 of the *Procedures for Calculating Cumulative Risk*.

[13] The IRIS oral RfD for 2,4-Dinitrotoluene is used as a surrogate for 2-Amino-4,6-Dinitrotoluene and 4-Amino-2,6-Dinitrotoluene.

[14] For unrestricted land use, the cleanup level for polychlorinated biphenyls (PCBs) is 1 mg/kg.

Table 7 Organic and Inorganic Chemical Specific Parameters

CAS Number[1]	Compound	VOC	D_a (cm^2/s)	D_w (cm^2/s)	Solubility (mg/L)	K_d (cm^3/g)	K_{oc} (cm^3/g)	H' (unitless)	MW (g/mol)	FA	Kp (cm/h)	Melting Point (°C)
83-32-9	Acenaphthene	Yes	0.0506143	8.33×10^{-6}	3.9	5.027	5027	0.00752248569092	154.21	1	0.086	93.4
208-96-8	Acenaphthylene	Yes	0.0449596	6.9822×10^{-6}	16.1	5.027	5027	0.00466067048242	152.2	1	0.0911	92.5
67-64-1	Acetone	Yes	0.1059215	0.0000115	1000000	0.002364	2.364	0.00143090760425	58.081	1	0.000512	-94.8
309-00-2	Aldrin	Yes	0.0228116	5.8402×10^{-6}	0.017	8202	8202.0	0.00179885527391	364.92	1	-	104
14797-73-0	Perchlorate and Perchlorate Salts	No	-	-	245000	0	-	-	117.49	1	0.001	-
120-12-7	Anthracene	Yes	0.0389732	7.8523×10^{-6}	0.0434	16.36	16360	0.00227309893704	178.24	1	0.142	215
7440-36-0	Antimony (metallic)	No	-	-	-	45	-	-	121.76	1	0.001	630.628
7440-38-2	Arsenic, Inorganic	No	-	-	-	29	-	-	74.922	1	0.001	270
7440-39-3	Barium	No	-	-	-	41	-	-	137.33	1	0.001	710
56-55-3	Benz[a]anthracene	Yes	0.0261138	6.7495×10^{-6}	0.0094	176.9	176900	0.00049059689288	228.3	1	-	84
100-52-7	Benzaldehyde	Yes	0.074393	9.4627×10^{-6}	6950	0.01109	11.09	0.00109157808667	106.13	1	0.00383	-26
71-43-2	Benzene	Yes	0.089534	0.0000103	1790	0.1458	145.8	0.226901062959 93	78.115	1	0.0149	5.5
50-32-8	Benzo[a]pyrene	No	0.0475831	5.5597×10^{-6}	0.00162	587.4	587400	0.0000186835 65	252.32	1	-	176.5
205-99-2	Benzo[b]fluoranthene	No	0.0475831	5.5597×10^{-6}	0.0015	599.4	599400	0.00002686017988	252.32	1	-	168
191-24-2	Benzo[g,h,i]perylene	No	0.0447842	5.2327×10^{-6}	0.00026	1951	1951000	0.00001353229762	276.34	0.7	-	278
207-08-9	Benzo[k]fluoranthene	No	0.0475831	5.5597×10^{-6}	0.0008	587.4	587400	0.00002387571545	252.32	0.9	-	217
65-85-0	Benzoic Acid	No	0.0701939	9.7868×10^{-6}	3400	0.0006	0.6	$1.5576451349141 \times 10^{-6}$	122.12	1	0.00565	122.4
100-51-6	Benzyl Alcohol	No	0.0731186	9.3665×10^{-6}	42900	0.02146	21.46	0.00001377759607	108.14	1	0.00209	-15.2
7440-41-7	Beryllium and compounds	No	-	-	-	790	-	-	9.01	1	0.001	986
111-44-4	Bis(2-chloroethyl)ether	Yes	0.0567192	8.707×10^{-6}	17200	0.03221	32.21	0.00036501226492	143.01	1	0.00178	-51.9
117-81-7	Bis(2-ethylhexyl)phthalate	No	0.0173403	4.1807×10^{-6}	0.27	119.6	119600	0.00001103843008	390.57	0.8	-	-55
108-86-1	Bromobenzene	Yes	0.0537132	9.3004×10^{-6}	446	0.2339	233.9	0.10098119378577	157.01	1	0.02	-30.6
75-27-4	Bromodichloromethane	Yes	0.0562629	0.0000107	3032	0.03182	31.82	0.08667211774325	163.83	1	0.00402	-57
75-25-2	Bromoform	Yes	0.0357324	0.0000104	3100	0.03182	31.82	0.02187244480784	252.73	1	0.00235	8
74-83-9	Bromomethane	Yes	0.1004976	0.0000135	15200	0.01322	13.22	0.30008176614881	94.939	1	0.00284	-93.7
106-99-0	Butadiene, 1,3-	Yes	0.1003488	0.0000103	735	0.0396	39.6	3.00899427636958	54.092	1	0.0164	-108.9
71-36-3	Butanol, N-	Yes	0.0900387	0.0000101	63200	0.003471	3.471	0.00036017988552	74.124	1	0.00231	-89.8
85-68-7	Butyl Benzyl Phthalate	No	0.0208319	5.1733×10^{-6}	2.69	7.155	7155	0.00005151267375	312.37	0.9	0.0585	-35
104-51-8	Butylbenzene, n-	Yes	0.0527732	7.3335×10^{-6}	11.8	1.482	1482	0.6500408830744	134.22	1	-	-87.9
135-98-8	Butylbenzene, sec-	Yes	0.0527928	7.3371×10^{-6}	17.6	1.331	1331	0.71954210956663	134.22	1	-	-82.7
98-06-6	Butylbenzene, tert-	Yes	0.0529525	7.3662×10^{-6}	29.5	1.001	1001	0.53965658217498	134.22	1	0.149	-57.8
7440-43-9	Cadmium	No	-	-	-	75	-	-	112.4	1	0.001	321
75-15-0	Carbon Disulfide	Yes	0.1064373	0.000013	2160	0.02173	21.73	0.58871627146361	76.139	1	0.0114	-111.5
56-23-5	Carbon Tetrachloride	Yes	0.0571435	9.7849×10^{-6}	793	0.04389	43.89	1.1283728536385 9	153.82	1	0.0163	-23
12789-03-6	Chlordane	Yes	0.021493	5.4477×10^{-6}	0.056	67.54	67540	0.00178691741618	409.78	0.7	0.107	106
143-50-0	Chlordecone (Kepone)	No	0.019647	4.9081×10^{-6}	2.7	17.5	17500	$2.1995094031071 \times 10^{-6}$	490.64	0.8	0.0109	350
106-47-8	Chloroaniline, p-	No	0.0703847	0.0000103	3900	0.1127	112.7	0.00004742436631	127.57	1	0.00496	72.5
108-90-7	Chlorobenzene	Yes	0.0721306	9.4765×10^{-6}	498	0.2339	233.9	0.12714636140637	112.56	1	0.0282	-45.2
67-66-3	Chloroform	Yes	0.0769197	0.0000109	7950	0.03182	31.82	0.1500408830744	119.38	1	0.00583	-63.6
74-87-3	Chloromethane	Yes	0.1239651	0.0000136	5320	0.01322	13.22	0.36058871627146	50.488	1	0.00328	-97.7
91-58-7	Chloronaphthalene, Beta-	Yes	0.0446914	7.7301×10^{-6}	11.7	2.478	2478	0.0130825838103	162.62	1	0.0749	61

CAS Number[1]	Compound	VOC	D_a (cm²/s)	D_w (cm²/s)	Solubility (mg/L)	K_d (cm³/g)	K_{oc} (cm³/g)	H' (unitless)	MW (g/mol)	FA	Kp (cm/h)	Melting Point (°C)
95-57-8	Chlorophenol, 2-	Yes	0.0661175	9.4784 x 10^{-6}	11300	0.388	388	0.000457890433336	128.56	1	0.00799	9.8
16065-83-1	Chromium(III), Insoluble Salts	No	-	-	-	1800000	-	-	52	1	0.001	-
18540-29-9	Chromium(VI)	No	-	-	1690000	19	-	-	52	1	0.002	-
218-01-9	Chrysene	No	0.0261138	6.7495 x 10^{-6}	0.002	180.5	180500	0.00021381847914	228.3	1	-	258.2
7440-50-8	Copper	No	-	-	-	35	-	-	63.546	1	0.001	1084.62
108-39-4	Cresol, m-	No	0.0728721	9.3232 x 10^{-6}	22700	0.3004	300.4	0.000034995911 69	108.14	1	0.00777	11.8
95-48-7	Cresol, o-	No	0.072835	9.3168 x 10^{-6}	25900	0.3065	306.5	0.000040905968928	108.14	1	0.00766	29.8
106-44-5	Cresol, p-	No	0.0723938	9.2397 x 10^{-6}	21500	0.3004	300.4	0.00004088307 44	108.14	1	0.00754	35.5
98-82-8	Cumene	Yes	0.0603044	7.8566 x 10^{-6}	61.3	0.6978	697.8	0.47015535568274	120.2	1	0.00897	-96
57-12-5	Cyanide (CN-)	Yes	0.2109549	0.0000246	95400	9.9	-	0.00415	26.018	1	0.001	-
110-82-7	Cyclohexane	Yes	0.0709729	9.1077 x 10^{-6}	55	0.1458	145.8	6.132461161079 31	84.163	1	0.102	6.6
72-54-8	DDD	No	0.0406077	4.7447 x 10^{-6}	0.09	117.5	117500	0.00026982829108	320.05	0.8	0.251	109.5
72-55-9	DDE, p,p'-	Yes	0.0229959	5.8592 x 10^{-6}	0.04	117.5	117500	0.00170073589533	318.03	0.8	-	89
50-29-3	DDT	No	0.037933	4.4322 x 10^{-6}	0.0055	168.6	168600	0.00034014717906	354.49	0.7	-	108.5
53-70-3	Dibenz[a,h]anthracene	No	0.0445672	5.2073 x 10^{-6}	0.00249	1912	1912000	5.764513491414 5 x 10^{-5}	278.36	0.6	-	269.5
132-64-9	Dibenzofuran	Yes	0.0650663	7.3773 x 10^{-6}	3.1	9.161	9161	0.00870809484873	168.2	1	0.0975	86.5
124-48-1	Dibromochloromethane	Yes	0.0366356	0.0000106	2700	0.03182	31.82	0.032011447260 83	208.28	1	0.00289	-20
106-93-4	Dibromoethane, 1,2-	Yes	0.0430348	0.0000104	3910	0.0396	39.6	0.02657399836467	187.86	1	0.00278	9.9
74-95-3	Dibromomethane (Methylene Bromide)	Yes	0.0551373	0.0000119	11900	0.02173	21.73	0.033605887162 71	173.84	1	0.00223	-52.5
84-74-2	Dibutyl Phthalate	No	0.0214362	5.3255 x 10^{-6}	11.2	1.157	1157	0.00007399836467	278.35	0.9	0.042	-35
95-50-1	Dichlorobenzene, 1,2-	Yes	0.0561703	8.9213 x 10^{-6}	156	0.3829	382.9	0.07849550286181	147	1	0.0446	-16.7
541-73-1	Dichlorobenzene, 1,3-	Yes	0.0558361	8.8494 x 10^{-6}	125	0.3753	375.3	0.10752248569092	147	1	0.052	-24.8
106-46-7	Dichlorobenzene, 1,4-	Yes	0.0550429	8.6797 x 10^{-6}	81.3	0.3753	375.3	0.09852820932134	147	1	0.0453	52.09
91-94-1	Dichlorobenzidine, 3,3'-	No	0.0474815	5.5478 x 10^{-6}	3.1	3.19	3190	1.161079313164 3 x 10^{-7}	253.13	1	0.0128	132
75-71-8	Dichlorodifluoromethane	Yes	0.0760293	0.0000108	280	0.04389	43.89	14.022894521668	120.91	1	0.00895	-158
75-34-3	Dichloroethane, 1,1-	Yes	0.0836446	0.0000106	5040	0.03182	31.82	0.22976287816843	98.96	1	0.00675	-96.9
107-06-2	Dichloroethane, 1,2-	Yes	0.0857221	0.000011	8600	0.0396	39.6	0.04824202780049	98.96	1	0.0042	-35.5
75-35-4	Dichloroethylene, 1,1-	Yes	0.0863107	0.000011	2420	0.03182	31.82	1.0670482420278	96.944	1	0.0117	-122.5
156-59-2	Dichloroethylene, 1,2-cis-	Yes	0.0884036	0.0000113	6410	0.0396	39.6	0.16680294358135	96.944	1	0.011	-80
156-60-5	Dichloroethylene, 1,2-trans-	Yes	0.0876094	0.0000112	4520	0.0396	39.6	0.38348323793949	96.944	1	0.011	-49.8
120-83-2	Dichlorophenol, 2,4-	No	0.0485768	8.6787 x 10^{-6}	5550	0.147	147	0.00017538838 92	163	1	0.0206	45
94-75-7	Dichlorophenoxy Acetic Acid, 2,4-	No	0.0279179	7.3445 x 10^{-6}	677	0.02963	29.63	1.447260834014 7 x 10^{-5}	221.04	1	0.00664	140.5
78-87-5	Dichloropropane, 1,2-	Yes	0.0733402	9.7252 x 10^{-6}	2800	0.0607	60.7	0.11529026982829	112.99	1	0.00753	-100
542-75-6	Dichloropropene, 1,3-	Yes	0.0762725	0.0000101	2800	0.07217	72.17	0.14513491414554	110.97	1	0.00834	-50
60-57-1	Dieldrin	No	0.0232865	6.0062 x 10^{-6}	0.195	20.09	20090	0.00040883074407	380.91	0.8	0.0326	175.5
84-66-2	Diethyl Phthalate	No	0.0260741	6.7227 x 10^{-6}	1080	0.1049	104.9	0.00002493867538	222.24	1	0.0036	-40.5
105-67-9	Dimethylphenol, 2,4-	No	0.0622451	8.314 x 10^{-6}	7870	0.4918	491.8	0.00003887980376	122.17	1	0.0109	24.5
131-11-3	Dimethylphthalate	No	0.0299117	7.1412 x 10^{-6}	4000	0.03159	31.59	8.053965658217 5 x 10^{-5}	194.19	1	0.00147	5.5
528-29-0	Dinitrobenzene, 1,2-	No	0.0447176	8.2538 x 10^{-6}	133	0.3588	358.8	2.179067865903 5 x 10^{-7}	168.11	1	0.00237	118.5
99-65-0	Dinitrobenzene, 1,3-	No	0.0484987	9.2109 x 10^{-6}	533	0.3516	351.6	2.003270645952 5 x 10^{-6}	168.11	1	0.00174	90
100-25-4	Dinitrobenzene, 1,4-	No	0.0491668	9.3849 x 10^{-6}	69	0.3516	351.6	3.430089942763 7 x 10^{-5}	168.11	1	0.00167	174
51-28-5	Dinitrophenol, 2,4-	No	0.0406699	9.0756 x 10^{-6}	2790	0.4608	460.8	3.515944399018 8 x 10^{-8}	184.11	1	0.00187	115.5
121-14-2	Dinitrotoluene, 2,4-	No	0.0375115	7.8982 x 10^{-6}	200	0.5756	575.6	2.207686017988 5 x 10^{-7}	182.14	1	0.00308	71

CAS Number[1]	Compound	VOC	D_a (cm^2/s)	D_w (cm^2/s)	Solubility (mg/L)	K_d (cm^3/g)	K_{oc} (cm^3/g)	H' (unitless)	MW[1] (g/mol)	FA	Kp (cm/h)	Melting Point (°C)
606-20-2	Dinitrotoluene, 2,6-	No	0.0370256	7.7629×10^{-6}	182	0.5874	587.4	0.000003053965658	182.14	1	0.0037	66
35572-78-2	Dinitrotoluene, 2-Amino-4,6-	No	0.0560905	6.5537×10^{-6}	1220	0.283	283	$1.3368765331152 \times 10^{-7}$	197.15	1	0.00204	174.5
19406-51-0	Dinitrotoluene, 4-Amino-2,6-	No	0.0560905	6.5537×10^{-6}	1220	0.283	283	$1.3368765331152 \times 10^{-7}$	197.15	1	0.00204	171
123-91-1	Dioxane, 1,4-	Yes	0.0873739	0.00001105	1000000	0.002633	2.633	0.000019623875715	88.107	1	0.000332	11.8
122-39-4	Diphenylamine	No	0.0417056	7.628×10^{-6}	53	0.8258	825.8	0.00010997547015	169.23	1	0.0373	52.9
115-29-7	Endosulfan	Yes	0.0224845	5.7629×10^{-6}	0.325	6.761	6761	0.00265739983646	406.93	0.9	0.00286	106
72-20-8	Endrin	No	0.0361581	4.2248×10^{-6}	0.25	20.09	20090	0.00026001635322	380.91	0.8	0.0326	226
75-00-3	Ethyl Chloride	Yes	0.1037597	0.00001116	6740	0.02173	21.73	0.45380212591986	64.515	1	0.00607	-138.7
100-41-4	Ethylbenzene	Yes	0.0684652	8.4558×10^{-6}	169	0.4461	446.1	0.3221586263287	106.17	1	0.0493	-94.9
107-21-1	Ethylene Glycol	No	0.116925	0.00001136	1000000	0.001	1	2.453×10^{-6}	62.069	1	0.0000877	-13
206-44-0	Fluoranthene	No	0.0275957	7.1827×10^{-6}	0.26	55.45	55450	0.00036222403924	202.26	1	-	107.8
86-73-7	Fluorene	Yes	0.0439743	7.889×10^{-6}	1.69	9.16	9160	0.00393295175797	166.22	1	0.1	114.8
50-00-0	Formaldehyde	Yes	0.1670871	0.0000174	400000	0.001	1	0.00001377759607	30.026	1	0.00182	-92
76-44-8	Heptachlor	Yes	0.0223441	5.6959×10^{-6}	0.18	41.26	41260	0.01201962387571	373.32	0.8	0.143	95.5
1024-57-3	Heptachlor Epoxide	Yes	0.0240006	6.2475×10^{-6}	0.2	10.11	10110	0.00085854456255	389.32	0.8	0.0209	160
118-74-1	Hexachlorobenzene	Yes	0.0289745	7.8497×10^{-6}	0.0062	6.195	6195	0.06950122649223	284.78	0.9	-	231.8
87-68-3	Hexachlorobutadiene	Yes	0.0267445	7.0264×10^{-6}	3.2	0.8452	845.2	0.42109566639411	260.76	0.9	0.081	-21
319-84-6	Hexachlorocyclohexane, Alpha-	No	0.043284	5.0574×10^{-6}	2	2.807	2807	0.00027391659852	290.83	0.9	0.0206	160
319-85-7	Hexachlorocyclohexane, Beta-	No	0.0276672	7.3955×10^{-6}	0.24	2.807	2807	0.00001798855273	290.83	0.9	0.0206	315
58-89-9	Hexachlorocyclohexane, Gamma- (Lindane)	No	0.043284	5.0574×10^{-6}	7.3	2.807	2807	0.00021013900245	290.83	0.9	0.0206	112.5
77-47-4	Hexachlorocyclopentadiene	Yes	0.0272382	7.217×10^{-6}	1.8	1.404	1404	1.10384300899428	272.77	0.9	0.103	-9
67-72-1	Hexachloroethane	Yes	0.0320938	8.8904×10^{-6}	50	0.1968	196.8	0.15903515944399	236.74	1	0.0415	187
121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	No	0.0311541	8.4989×10^{-6}	59.7	0.08907	89.07	$8.2174979558462 \times 10^{-10}$	222.12	1	0.000336	205.5
110-54-3	Hexane, N-	Yes	0.0731078	8.1657×10^{-6}	9.5	0.1315	131.5	73.58955339329518	86.178	1	0.201	-95.3
591-78-6	Hexanone, 2-	Yes	0.0703564	8.4404×10^{-6}	17200	0.01498	14.98	0.00381030253475	100.16	1	0.00355	-55.5
302-01-2	Hydrazine[3]	Yes	0.1733034	0.000019	1000000	0.002	2	0.000025	32.045	1	0.0000436	2
193-39-5	Indeno[1,2,3-cd]pyrene	No	0.0447842	5.2327×10^{-6}	0.00019	1951	1951000	0.00001422730989	276.34	0.6	-	163.6
78-59-1	Isophorone	No	0.0525048	7.5296×10^{-6}	12000	0.06515	65.15	0.00027146361406	138.21	1	0.00354	-8.1
67-63-0	Isopropanol	Yes	0.1032261	0.0000112	1000000	0.00153	1.53	0.00033115290269	60.097	1	0.0007778	-89.5
7439-92-1	Lead and Compounds	No	-	-	-	900	-	-	207.2	1	0.0001	327.5
7439-96-5	Manganese, Total	No	-	-	-	65	-	-	54.938	1	0.001	1200
7487-94-7	Mercuric Chloride	No	-	-	69000	52	-	-	271.5	1	0.001	277
7439-97-6	Mercury (elemental)	Yes	0.0307	6.3×10^{-6}	0.06	52	-	0.352	200.59	1	0.001	-38.8
67-56-1	Methanol	Yes	0.1582741	0.0000165	1000000	0.001	1	0.00018601798855	32.042	1	0.000319	-97.6
72-43-5	Methoxychlor	No	0.0220849	5.5926×10^{-6}	0.1	26.89	26890	$8.299264104660 6 \times 10^{-6}$	345.66	0.8	0.0428	87
78-93-3	Methyl Ethyl Ketone (2-Butanone)	Yes	0.0914462	0.0000102	223000	0.00451	4.51	0.00232624693376	72.108	1	0.000962	-86.6
108-10-1	Methyl Isobutyl Ketone (4-methyl-2-pentanone)	Yes	0.0697797	8.3477×10^{-6}	19000	0.0126	12.6	0.00564186426819	100.16	1	0.00319	-84
22967-92-6	Methyl Mercury[4]	No	-	-	-	7000	-	-	216.6326	1	0.001	-
1634-04-4	Methyl tert-Butyl Ether (MTBE)	Yes	0.0752672	8.5905×10^{-6}	51000	0.01156	11.56	0.02399836467702	88.151	1	0.00211	-108.6
75-09-2	Methylene Chloride	Yes	0.0989362	0.0000125	13000	0.02173	21.73	0.13286999182338	84.933	1	0.00354	-95.1
90-12-0	Methylnaphthalene, 1-	Yes	0.0527705	7.8477×10^{-6}	25.8	2.528	2528	0.02101390024529	142.2	1	0.0931	34
91-57-6	Methylnaphthalene, 2-	Yes	0.0524319	7.7811×10^{-6}	24.6	2.478	2478	0.02117743254292	142.2	1	0.0917	34.4
91-20-3	Naphthalene	Yes	0.0604994	8.377×10^{-6}	31	1.544	1544	0.01798855273916	128.18	1	0.0466	80.2

CAS Number[1]	Compound	VOC	D_a (cm²/s)	D_w (cm²/s)	Solubility (mg/L)	K_d (cm³/g)	K_{oc} (cm³/g)	H' (unitless)	MW (g/mol)	FA	Kp (cm/h)	Melting Point (°C)
7440-02-0	Nickel Soluble Salts	No	-			65		-	58.71	1	0.0002	1455
98-95-3	Nitrobenzene	Yes	0.068054	9.4495×10^{-6}	2090	0.2264	226.4	0.00098119378577	123.11	1	0.00541	5.7
55-63-0	Nitroglycerin	No	0.029015	7.7428×10^{-7}	1380	0.1158	115.8	$3.5404742436631 \times 10^{-5}$	227.09	1	0.000994	13.5
556-88-7	Nitroguanidine	No	0.0996937	0.0000142	4400	0.02065	20.65	$1.8192968111202 \times 10^{-11}$	104.07	1	0.000105	239
62-75-9	Nitrosodimethylamine, N-	Yes	0.0987674	0.0000115	1000000	0.02279	22.79	0.00007440719542	74.083	1	0.000251	-39.07
621-64-7	Nitroso-di-N-propylamine, N-	No	0.0564399	7.758×10^{-6}	13000	0.2754	275.4	0.00021995094031	130.19	1	0.00233	6.81
86-30-6	Nitrosodiphenylamine, N-	No	0.0558866	6.5299×10^{-7}	35	2.632	2632	0.00004946852003	198.23	1	0.0145	66.5
99-08-1	Nitrotoluene, m-	No	0.058686	8.6541×10^{-6}	500	0.3632	363.2	0.00038021259198	137.14	1	0.0113	15.5
88-72-2	Nitrotoluene, o-	Yes	0.0587535	8.6675×10^{-6}	650	0.3706	370.6	0.00051103843008	137.14	1	0.00899	-10
99-99-0	Nitrotoluene, p-	No	0.0574432	8.4083×10^{-6}	442	0.3632	363.2	0.00023017170891	137.14	1	0.01	51.6
2691-41-0	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	No	0.0427631	4.9965×10^{-7}	5	0.5316	531.6	$3.5445625511038 \times 10^{-5}$	296.16	1	0.0000436	286
117-84-0	Octyl Phthalate, di-N-	No	0.0355594	4.1548×10^{-6}	0.022	140.8	140800	0.00010506950122	390.57	0	-	25
87-86-5	Pentachlorophenol	No	0.0295197	8.0121×10^{-6}	14	0.592	592	$1.0016353229762 \times 10^{-6}$	266.34	0.9	0.127	174
78-11-5	Pentaerythritol tetranitrate (PETN)	No	0.025756	6.7697×10^{-6}	43	0.6479	647.9	$5.3965658217498 \times 10^{-4}$	316.14	1	0.00101	140.5
1763-23-1	Perfluorooctane sulfonic acid (PFOS)[7,8]	No	0.0207478	5.2533×10^{-7}	680	0.3715	371.5	-	500.13	0	-	51.9
335-67-1	Perfluorooctanoic Acid (PFOA)[8]	No	0.02257	5.7947×10^{-6}	9500	0.1148	114.8	-	414.07	0	-	55
85-01-8	Phenanthrene	Yes	0.0344784	6.6897×10^{-6}	1.15	16.69	16690	0.00172935404742	178.24	1	0.144	99.2
108-95-2	Phenol	No	0.0833983	0.0000103	82800	0.1872	187.2	0.00001361406377	94.114	1	0.00434	40.9
7723-14-0	Phosphorus, White	Yes	0.2193655	0.0000277	3	3.5	1122	0.086	30.974	1	0.001	44.15
1336-36-3	Polychlorinated Biphenyls	Yes	0.0243397	6.2671×10^{-6}	0.7	78.1	78100	0.01696647587898	291.99	0.7	-	122.32
103-65-1	Propyl benzene	Yes	0.0601558	7.831×10^{-7}	52.2	0.8131	813.1	0.42927228127555	120.2	1	0.0939	-99.5
129-00-0	Pyrene	Yes	0.0277873	7.2479×10^{-6}	0.135	54.34	54340	0.00048650858544	202.26	1	0.201	151.2
7782-49-2	Selenium	No	-	-	-	5	-	-	78.96	1	0.001	221
7440-22-4	Silver	No	-	-	-	8.3	-	-	107.87	1	0.0006	961.78
7440-24-6	Strontium, Total	No				35			87.62	1	0.001	780
100-42-5	Styrene	Yes	0.071114	8.7838×10^{-6}	310	0.4461	446.1	0.11242845461978	104.15	1	0.0372	-31
1746-01-6	TCDD, 2,3,7,8-	Yes	0.0470278	6.7568×10^{-7}	0.0002	249.1	249100	0.00204415372035	321.98	0.5	-	305
630-20-6	Tetrachloroethane, 1,1,1,2-	Yes	0.0481761	9.0977×10^{-6}	1070	0.08603	86.03	0.10220768601798	167.85	1	0.0159	-70.2
79-34-5	Tetrachloroethane, 1,1,2,2-	Yes	0.0489206	9.2902×10^{-6}	2830	0.09494	94.94	0.01500408830744	167.85	1	0.00694	-43.8
127-18-4	Tetrachloroethylene	Yes	0.0504664	9.4551×10^{-6}	206	0.09494	94.94	0.72363041700735	165.83	1	0.0334	-22.3
479-45-8	Tetryl (Trinitrophenylmethylnitramine)	No	0.0255626	6.6672×10^{-7}	74	4.605	4605	$1.1079513164335 \times 10^{-7}$	287.15	1	0.000474	131.5
7440-28-0	Thallium (Soluble Salts)	No	-	-	-	71	-	-	204.38	1	0.001	303.5
108-88-3	Toluene	Yes	0.0778039	9.2045×10^{-6}	526	0.2339	233.9	0.27146361406377	92.142	1	0.0311	-94.9
8001-35-2	Toxaphene	No	0.032439	3.7902×10^{-6}	0.55	77.2	77200	0.00024529844644	448.26	0.8	-	77
76-13-1	Trichloro-1,2,2-trifluoroethane, 1,1,2-	Yes	0.0375658	8.592×10^{-6}	170	0.1968	196.8	21.504497138184 8	187.38	1	0.0175	35
87-61-6	Trichlorobenzene, 1,2,3-	Yes	0.03953	8.3836×10^{-6}	18	1.383	1383	0.05110384300899	181.45	1	0.0738	53.5
120-82-1	Trichlorobenzene, 1,2,4-	Yes	0.0395902	8.4033×10^{-6}	49	1.356	1356	0.05805396565821	181.45	1	0.0705	17
71-55-6	Trichloroethane, 1,1,1-	Yes	0.0648174	9.599×10^{-6}	1290	0.04389	43.89	0.70318887980376	133.41	1	0.0126	-30.4
79-00-5	Trichloroethane, 1,1,2-	Yes	0.0668004	0.00001	4590	0.0607	60.7	0.03368765331152	133.41	1	0.00504	-36.6
79-01-6	Trichloroethylene	Yes	0.0686618	0.0000102	1280	0.0607	60.7	0.40269828291087	131.39	1	0.0116	-84.7
75-69-4	Trichlorofluoromethane	Yes	0.065356	0.00001	1100	0.04389	43.89	3.9656582174979 6	137.37	1	0.0127	-111.1
95-95-4	Trichlorophenol, 2,4,5-	No	0.0313938	8.0893×10^{-6}	1200	1.597	1597	0.00006623058053	197.45	1	0.0362	69
88-06-2	Trichlorophenol, 2,4,6-	No	0.0313948	8.0896×10^{-6}	800	0.381	381	0.00010629599345	197.45	1	0.0346	69

CAS Number[1]	Compound	VOC	D_a (cm^2/s)	D_w (cm^2/s)	Solubility (mg/L)	K_d (cm^3/g)	K_{oc} (cm^3/g)	H' (unitless)	MW (g/mol)	FA	Kp (cm/h)	Melting Point (°C)
93-76-5	Trichlorophenoxyacetic Acid, 2,4,5-	No	0.0288853	7.7627×10^{-6}	278	0.107	107	$3.5486508585445 \times 10^{-7}$	255.49	0.9	0.00914	153
93-72-1	Trichlorophenoxypropionic acid, 2,4,5	No	0.0233585	5.9194×10^{-6}	71	0.1753	175.3	$3.7040065412919 \times 10^{-7}$	269.51	0.9	0.0161	181.6
96-18-4	Trichloropropane, 1,2,3-	Yes	0.0574661	9.2411×10^{-6}	1750	0.1158	115.8	0.01402289452166	147.43	1	0.00752	-14.7
95-63-6	Trimethylbenzene, 1,2,4-	Yes	0.0606754	7.9209×10^{-6}	57	0.6143	614.3	0.25183973834832	120.2	1	0.0857	-43.8
108-67-8	Trimethylbenzene, 1,3,5-	Yes	0.0602254	7.843×10^{-6}	48.2	0.6021	602.1	0.3585445625511	120.2	1	0.0621	-44.7
688-73-3	Tri-n-butyltin	Yes	0.0214738	5.351×10^{-6}	0.0073	8.091	8091	62.142273098937	291.05	0.9	0.0193	28.89
99-35-4	Trinitrobenzene, 1,3,5-	No	0.0289685	7.6882×10^{-6}	278	1.683	1683	$2.6573998364677 \times 10^{-7}$	213.11	1	0.000607	121.5
118-96-7	Trinitrotoluene, 2,4,6-	No	0.0295093	7.9182×10^{-6}	115	2.812	2812	$8.5036794766966 \times 10^{-7}$	227.13	1	0.000963	80.1
7440-62-2	Vanadium and Compounds	No	-	-	-	1000	-	-	50.94	1	0.001	1910
108-05-4	Vinyl Acetate	Yes	0.0849016	0.00001	20000	0.005583	5.583	0.02089125102207	86.091	1	0.00157	-93.2
75-01-4	Vinyl Chloride	Yes	0.1071202	0.000012	8800	0.02173	21.73	1.13654946852003	62.499	1	0.00838	-153.7
1330-20-7	Xylenes	Yes	0.0685148	8.4641×10^{-6}	106	0.3829	382.9	0.2710547833197	106.17	1	0.05	-25.2
7440-66-6	Zinc and Compounds	No	-	-	-	62	-	-	65.37	1	0.0006	419.5

Sources for the parameters listed in this table were obtained using the chemical parameter hierarchy found in Section 1.0 of this document.

[1] "CAS Number" means the Chemical Abstract Service (CAS) registry number uniquely assigned to chemicals by the American Chemical Society and recorded in the CAS Registry System

[2] "c" means carcinogenic, "nc" means noncarcinogenic, and "m" means mutagenic

[3] Hydrazine Kd value is taken from the National Institute of Health's Toxic Substances Databank

[4] Methyl mercury Kd value is taken from U.S. EPA. 1997 Mercury Study Report to Congress. EPA-452/R-97-005. Office of Air Quality Planning and Standards and Office of Research and Development. Decemaber

[5] PFOS and PFOA Koc values are taken from Higgins C and Luthy R. (2006) Sorption of Perfluorinated Surfactants on Sediments. Environ Sci Technol. 40(23):7251-7256.

[6] Perfluorooctane Sulfonic Acid includes both the acid and its salt.

Appendix B – Table 8 - Standard Default Factors for Non-Petroleum Organic and Inorganic Contaminants

Symbol	Definition (units)	Default	Reference(s)
A	Dispersion constant (unitless)	Arctic Zone = 17.6482 Under 40" Zone = 16.2302 Over 40" Zone = 14.2253	U.S. EPA 2002 Harding Lawson Associates
AF	Attenuation factor (unitless)	4	Professional judgment
AF_{0-2}	Skin adherence factor – age segment 0 – 2 years old (mg/cm^2)	0.2	U.S. EPA 2004
AF_{2-6}	Skin adherence factor – age segment 2 – 6 years old (mg/cm^2)	0.2	U.S. EPA 2004
AF_{6-16}	Skin adherence factor – age segment 6 – 16 years old (mg/cm^2)	0.07	U.S. EPA 2004
AF_{16-26}	Skin adherence factor – age segment 16 – 26 years old (mg/cm^2)	0.07	U.S. EPA 2004
AF_{iw}	Skin adherence factor – indoor worker (mg/cm^2)	0.12	U.S. EPA 2011
AF_{ow}	Skin adherence factor – indoor worker (mg/cm^2)	0.12	U.S. EPA 2011
AF_{resa}	Skin adherence factor – resident soil adult (mg/cm^2)	0.07	U.S. EPA 2004
AF_{resc}	Skin adherence factor – resident soil child (mg/cm^2)	0.2	U.S. EPA 2004
	Areal extent of the site or contamination (acres)	0.5	U.S. EPA 2002
AT_{iw}	Averaging time – indoor worker (days)	$365 \times ED_{iws} = 9125$	U.S. EPA 1989
AT_{ow}	Averaging time – outdoor worker (days)	$365 \times ED_{ows} = 9125$	U.S. EPA 1989
AT_{res}	Averaging time – resident soil (days)	$365 \times LT = 25550$	U.S. EPA 1989
AT_{resa}	Averaging time – resident soil adult (days)	$365 \times ED_{resa} = 9490$	U.S. EPA 1989
AT_{resc}	Averaging time – resident soil child (days)	$365 \times ED_{resc} = 2190$	U.S. EPA 1989
AT_{resw}	Averaging time – resident groundwater (days)	$365 \times LT = 25550$	U.S. EPA 1989
AT_{reswa}	Averaging time – resident groundwater adult (days)	$365 \times ED_{reswa} = 9490$	U.S. EPA 1989
AT_{reswc}	Averaging time – resident groundwater child (days)	$365 \times ED_{reswc} = 2190$	U.S. EPA 1989
B	Dispersion constant (unitless)	Arctic Zone = 18.8138 Under 40" Zone = 18.7762 Over 40" Zone = 18.8366	U.S. EPA 2002 Harding Lawson Associates
BW_{0-2}	Body weight – age segment 0 – 2 years old (kg)	15	U.S. EPA 2011
BW_{2-6}	Body weight – age segment 2 – 6 years old (kg)	15	U.S. EPA 2011

Symbol	Definition (units)	Default	Reference(s)
BW_{6-16}	Body weight – age segment 6 – 16 years old (kg)	80	U.S. EPA 2011
BW_{16-26}	Body weight – age segment 16 – 26 years old (kg)	80	U.S. EPA 2011
BW_{iw}	Body weight – indoor worker (kg)	80	U.S. EPA 2011
BW_{ow}	Body weight – outdoor worker (kg)	80	U.S. EPA 2011
BW_{resa}	Body weight –adult (kg)	80	U.S. EPA 2011
BW_{resc}	Body weight –child (kg)	15	U.S. EPA 2011
BW_{resa}	Body weight –adult (kg)	80	U.S. EPA 2011
BW_{resc}	Body weight –child (kg)	15	U.S. EPA 2011
C	Dispersion constant (unitless)	Arctic Zone = 217.039 Under 40" Zone = 216.108 Over 40" Zone = 218.1845	U.S. EPA 2002 Harding Lawson Associates
d	Mixing zone depth (m)	5.5	U.S. EPA. 2002
d_a	Aquifer thickness (m)	10	U.S. EPA. 2002
d_s	Depth of source (m)	5.5	U.S. EPA. 2002
DAF	Dilution attenuation factor (unitless)	13.2	U.S. EPA. 2002
DF	Dilution factor (unitless)	3.3	Professional judgment
$DFSM_{res-adj}$	Mutagenic dermal contact factor – resident soil age-adjusted (mg/kg)	Arctic Zone = 244720 Under 40" Zone = 330372 Over 40" Zone = 403788	Calculated using the age adjusted intake factors equation
$DFS_{res-adj}$	Dermal contact factor – resident soil age-adjusted (mg/kg)	Arctic Zone = 59080 Under 40" Zone = 79758 Over 40" Zone =97482	Calculated using the age adjusted intake factors equation
$DFWM_{res-adj}$	Mutagenic dermal contact factor – resident groundwater age-adjusted (cm^2 - event/kg)	8191633	Calculated using the age adjusted intake factors equation
$DFW_{res-adj}$	Dermal contact factor – resident groundwater age-adjusted (cm^2 - event/kg)	2610650	Calculated using the age adjusted intake factors equation
ED_{0-2}	Exposure duration – age segment 0 – 2 years old (years)	2	Time Frame
ED_{2-6}	Exposure duration – age segment 2 – 6 years old (years)	4	Time Frame
ED_{6-16}	Exposure duration – age segment 6 – 16 years old (years)	10	Time Frame

Symbol	Definition (units)	Default	Reference(s)
ED_{16-26}	Exposure duration – age segment 16 – 26 years old (years)	10	Time Frame
ED_{iw}	Exposure duration – indoor worker (years)	25	U.S. EPA 1991a
ED_{ow}	Exposure duration – outdoor worker (years)	25	U.S. EPA 1991a
ED_{ress}	Exposure duration – resident soil (years)	26	EPA 2011
ED_{ressa}	Exposure duration – resident soil adult (years)	20	U.S. EPA 1991a
ED_{ressc}	Exposure duration – resident soil child (years)	6	U.S. EPA 1991a
ED_{resw}	Exposure duration – resident groundwater (years)	26	EPA 2011
ED_{reswa}	Exposure duration – resident groundwater adult (years)	20	U.S. EPA 1991a
ED_{reswc}	Exposure duration – resident groundwater child (years)	6	U.S. EPA 1991a
EF_{0-2}	Exposure frequency – age segment 0 – 2 years old (days/year)	Arctic Zone = 200 Under 40" Zone = 270 Over 40" Zone = 330 Migration to Groundwater = 350 Groundwater = 350	Harding Lawson Associates
$_{2-6}$	Exposure frequency – age segment 2 – 6 years old (days/year)	Arctic Zone = 200 Under 40" Zone = 270 Over 40" Zone = 330 Migration to Groundwater = 350 Groundwater = 350	Harding Lawson Associates
EF_{6-16}	Exposure frequency – age segment 6 – 16 years old (days/year)	Arctic Zone = 200 Under 40" Zone = 270 Over 40" Zone = 330 Migration to Groundwater = 350 Groundwater = 350	Harding Lawson Associates
EF_{16-26}	Exposure frequency – age segment 16 – 26 years old (days/year)	Arctic Zone = 200 Under 40" Zone = 270 Over 40" Zone = 330 Migration to Groundwater = 350 Groundwater = 350	Harding Lawson Associates
EF_{iws}	Exposure frequency – indoor worker soil (days/year)	Arctic Zone = 200 Under 40" Zone = 250 Over 40" Zone = 250	Harding Lawson Associates

Symbol	Definition (units)	Default	Reference(s)
EF_{ows}	Exposure frequency – outdoor worker soil (days/year)	Arctic Zone = 200 Under 40" Zone = 250 Over 40" Zone = 250	Harding Lawson Associates
EF_{ress}	Exposure frequency - resident soil (days/year)	Arctic Zone = 200 Under 40" Zone = 270 Over 40" Zone = 330	Harding Lawson Associates
EF_{ressa}	Exposure frequency – resident soil adult (days/year)	Arctic Zone = 200 Under 40" Zone = 270 Over 40" Zone = 330	Harding Lawson Associates
EF_{ressc}	Exposure frequency – resident soil child (days/year)	Arctic Zone = 200 Under 40" Zone = 270 Over 40" Zone = 330	Harding Lawson Associates
EF_{resw}	Exposure frequency – resident groundwater (days/year)	350	U.S. EPA 1991a
EF_{reswa}	Exposure frequency – resident groundwater adult (days/year)	350	U.S. EPA 1991a
EF_{reswc}	Exposure frequency – resident groundwater child (days/year)	350	U.S. EPA 1991a
ET_{0-2}	Exposure time - age segment 0 – 2 years old (hours/day)	24	The whole day
ET_{2-6}	Exposure time - age segment 2 – 6 years old (hours/day)	24	The whole day
ET_{6-16}	Exposure time - age segment 6 – 16 years old (hours/day)	24	The whole day
ET_{16-26}	Exposure time - age segment 16 – 26 years old (hours/day)	24	The whole day
ET_{0-2}^{der}	Dermal exposure time - age segment 0 – 2 years old (hours/event)	0.54	U.S. EPA 2011
ET_{2-6}^{der}	Dermal exposure time - age segment 2 – 6 years old (hours/event)	0.54	U.S. EPA 2011
ET_{6-16}^{der}	Dermal exposure time - age segment 6 – 16 years old (hours/event)	0.71	U.S. EPA 2011
ET_{16-26}^{der}	Dermal exposure time - age segment 16 – 26 years old (hours/event)	0.71	U.S. EPA 2011
ET_{0-2}^{inh}	Inhalation exposure time - age segment 0 – 2 years old (hours/event)	24	The whole day
ET_{2-6}^{inh}	Inhalation exposure time - age segment 2 – 6 years old (hours/event)	24	The whole day
ET_{6-16}^{inh}	Inhalation exposure time - age segment 6 – 16 years old (hours/event)	24	The whole day
ET_{16-26}^{inh}	Inhalation exposure time - age segment 16 – 26 years old (hours/event)	24	The whole day
ET_{ress}	Exposure time - resident soil (hours/day)	24	The whole day
ET_{ressa}	Exposure time – resident soil adult (hours/day)	24	The whole day
ET_{ressc}	Exposure time – resident soil child (hours/day)	24	The whole day

Symbol	Definition (units)	Default	Reference(s)
ET_{resw}	Exposure time – resident groundwater (hours/day)	24	The whole day
ET_{resw}^{inh}	Inhalation exposure time – resident groundwater (hours/day)	24	The whole day
ET_{reswa}^{der}	Dermal exposure time – resident groundwater adult (hours/event)	0.71	U.S. EPA 2011
ET_{reswa}^{inh}	Inhalation exposure time – resident groundwater adult (hours/event)	24	The whole day
ET_{reswc}^{der}	Dermal exposure time – resident groundwater child (hours/event)	0.54	U.S. EPA 2011
ET_{reswc}^{inh}	Inhalation exposure time – resident groundwater child (hours/event)	24	The whole day
$ET_{resw\text{-}adj}^{der}$	Dermal exposure time – resident groundwater age-adjusted (hours/day)	0.67077	U.S. EPA 2011
$ET_{resw\text{-}adj}^{inh}$	Inhalation exposure time – resident groundwater age-adjusted (hours/day)	24	The whole day
$ET_{resw\text{-}madj}$	Mutagenic exposure time – resident groundwater age-adjusted (hours/day)	0.67077	U.S. EPA 2011
$EV_{0\text{-}2}$	Exposure events – age segment 0 – 2 years old (events/day)	1	U.S. EPA 2011
$EV_{2\text{-}6}$	Exposure events – age segment 2 – 6 years old (events/day)	1	U.S. EPA 2011
$EV_{6\text{-}16}$	Exposure events – age segment 6 – 16 years old (events/day)	1	U.S. EPA 2011
$EV_{16\text{-}26}$	Exposure events – age segment 16 – 26 years old (events/day)	1	U.S. EPA 2011
EV_{reswa}	Exposure events – resident groundwater adult (events/day)	1	U.S. EPA 2011
EV_{reswc}	Exposure events – resident groundwater child (events/day)	1	U.S. EPA 2011
F(x)	Function dependent on u_m / u_t (unitless)	Arctic Zone = 0.57 Under 40" Zone = 0.194 Over 40" Zone = 0.0616	U.S. EPA 1996a
f_{oc}	Fraction organic carbon in soil (g/g)	0.001 (0.1%)	U.S. EPA. 2002
I	Infiltration rate (m/year)	0.13	U.S. EPA. 2002

Symbol	Definition (units)	Default	Reference(s)
i	Hydraulic gradient (m/m)	0.002	U.S. EPA. 2002
$IFSM_{res\text{-}adj}$	Mutagenic soil ingestion rate – resident age-adjusted (mg/kg)	Arctic Zone = 95333 Under 40" Zone = 128700 Over 40" Zone = 157300	Calculated using the age adjusted intake factors equation
$IFS_{res\text{-}adj}$	Soil ingestion rate – resident age-adjusted (mg/kg)	Arctic Zone = 21000 Under 40" Zone = 28350 Over 40" Zone = 34650	Calculated using the age adjusted intake factors equation
$IFWM_{res\text{-}adj}$	Mutagenic groundwater ingestion rate – resident age-adjusted (L/kg)	1019.9	Calculated using the age adjusted intake factors equation
$IFW_{res\text{-}adj}$	Groundwater ingestion rate – resident age-adjusted (L/kg)	327.95	Calculated using the age adjusted intake factors equation
$IRS_{0\text{-}2}$	Soil ingestion rate - age-segment 0 – 2 years old (mg/day)	200	U.S. EPA 1991a (pg. 15)
$IRS_{2\text{-}6}$	Soil ingestion rate - age-segment 2 – 6 years old (mg/day)	200	U.S. EPA 1991a (
$IRS_{6\text{-}16}$	Soil ingestion rate - age-segment 6 – 16 years old (mg/day)	100	U.S. EPA 1991a
$IRS_{16\text{-}26}$	Soil ingestion rate - age-segment 16 – 26 years old (mg/day)	100	U.S. EPA 1991a
IRS_{iw}	Soil ingestion rate – indoor worker (mg/day)	50	U.S. EPA 1991a
IRS_{ow}	Soil ingestion rate – outdoor worker (mg/day)	100	U.S. EPA 1991a
IRS_{resa}	Soil ingestion rate – resident soil adult (mg/day)	100	U.S. EPA 1991a
IRS_{resc}	Soil ingestion rate – resident soil child (mg/day)	200	U.S. EPA 1991a
$IRW_{0\text{-}2}$	Resident groundwater ingestion rate - age-segment 0 – 2 years old (L/day)	0.78	U.S. EPA 2011
$IRW_{2\text{-}6}$	Resident groundwater ingestion rate - age-segment 2 – 6 years old (L/day)	0.78	U.S. EPA 2011
$IRW_{6\text{-}16}$	Resident groundwater ingestion rate - age-segment 6 – 16 years old (L/day)	2.5	U.S. EPA 2011
$IRW_{16\text{-}26}$	Resident groundwater ingestion rate - age-segment 16 – 26 years old (L/day)	2.5	U.S. EPA 2011
IRW_{iw}	Groundwater ingestion rate – indoor worker (L/day)	2.5	U.S. EPA 2011
IRW_{ow}	Groundwater ingestion rate – outdoor worker (L/day)	2.5	U.S. EPA 2011
IRW_{resa}	Groundwater ingestion rate – resident groundwater adult (L/day)	2.5	U.S. EPA 2011
IRW_{resc}	Groundwater ingestion rate – resident groundwater child (L/day)	0.78	U.S. EPA 2011

Symbol	Definition (units)	Default	Reference(s)
K	Andelman volatilization factor (L/m^3)	0.5	U.S. EPA 1991b
K	Aquifer hydraulic conductivity (m/year)	876	U.S. EPA. 2002
L	Source length parallel to ground water flow (m)	32	U.S. EPA. 2002
LT	Lifetime (years)	70	U.S. EPA 1989
n	Total soil porosity(L_{pore}/L_{soil})	$= 1-(\rho_b/\rho_s) = 0.43396$	U.S. EPA. 2002
PEF_w	Particulate emission factor (m^3/kg)	Arctic Zone = 1.47×10^9 Under 40" Zone = 1.36×10^9 Over 40" Zone = 1.28×10^9	Determined in the calculations
Q/C	Inverse of the mean concentration at the center of a 0.5-acre-square source (g/m^2-s per kg/m^3)	Arctic Zone = 101.5958 Under 40" Zone = 93.7736 Over 40" Zone = 81.7066	Harding Lawson Associates
SA_{0-2}	Skin surface area – resident age segment 0 – 2 years old (cm^2)	Soil = 2373 Migration to Groundwater = 6365 Groundwater = 6365	U.S. EPA 2011
SA_{2-6}	Skin surface area – resident age segment 2 – 6 years old (cm^2)	Soil = 2373 Migration to Groundwater = 6365 Groundwater = 6365	U.S. EPA 2011
SA_{6-16}	Skin surface area – resident age segment 6 – 16 years (cm^2)	Soil = 6032 Migration to Groundwater = 19652 Groundwater = 20900	U.S. EPA 2011
SA_{16-26}	Skin surface area – resident age segment 16 – 26 years (cm^2)	Soil = 6032 Migration to Groundwater = 19652 Groundwater = 20900	U.S. EPA 2011
SA_{iw}	Skin surface area – indoor worker (cm^2)	3527	US EPA 2011
SA_{ow}	Skin surface area – outdoor worker (cm^2)	3527	US EPA 2011
SA_{resa}	Skin surface area – resident soil adult (cm^2)	6032	U.S. EPA 2011
SA_{resc}	Skin surface area – resident soil child (cm^2)	2373	U.S. EPA 2011
SA_{resga}	Skin surface area – resident groundwater adult (cm^2)	19652	U.S. EPA 2011
SA_{resgc}	Skin surface area – resident groundwater child (cm^2)	6365	U.S. EPA 2011
T	Exposure interval (s)	819936000	U.S. EPA. 2002
THQ	Target hazard quotient	1.0	18 AAC 75.990(50)

Symbol	Definition (units)	Default	Reference(s)
TR	Target risk	1×10^{-5}	Determined in this calculator
U_m	Mean annual wind speed (m/s)	Arctic Zone = 5.77 Under 40" Zone = 4.69 Over 40" Zone = 4.07	U.S. EPA 1996a
U_t	Equivalent threshold value of wind speed at 7m (m/s)	11.32	U.S. EPA 1996a
V	Fraction of vegetative cover (unitless)	0.5	U.S. EPA 1996a
θ_a	Air-filled soil porosity (L_{air}/L_{soil})	$= n-\theta_w = 0.28396$	U.S. EPA. 2002
θ_w	Water-filled soil porosity (L_{water}/L_{soil})	0.15	U.S. EPA. 2002
ρ_b	Dry soil bulk density (kg/L)	1.5	U.S. EPA. 2002
ρ_s	Soil particle density (kg/L)	2.65	U.S. EPA. 2002

References for Cited Sources:

Harding Lawson Associates. 1995. Final Report Cleanup Level Matrix for Hazardous Substances in Soil Various Sites, Alaska.

U.S. EPA 1989. Risk assessment guidance for Superfund. Volume I: Human health evaluation manual (Part A). Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002.

U.S.EPA 1991a. Human health evaluation manual, supplemental guidance: "Standard default exposure factors". OSWER Directive 9285.6-03.

U.S. EPA 1991b. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals). Office of Emergency and Remedial

U.S. EPA. 1996a. Soil Screening Guidance: User's Guide. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4

U.S.EPA. 1996b. Soil Screening Guidance: Technical Background Document. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4

U.S.EPA 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. December 2002.http://www.epa.gov/superfund/health/conmedia/soil/index.htm

U.S. EPA 2011. Exposure Factors Handbook: 2011 Edition. EPA/ 600/ R-090/052F, September 2011.

State of Alaska

DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF SPILL PREVENTION AND RESPONSE
CONTAMINATED SITES PROGRAM

Procedures for Calculating Cumulative Risk

February 1, 2018

Adopted by Reference at 18 AAC 75

Procedures for Calculating Cumulative Risk

TABLE OF CONTENTS

1.0 INTRODUCTION

The Alaska Department of Environmental Conservation (DEC) has developed rules at 18 AAC 75, Article 3 that detail the extent of cleanup required at contaminated sites in order to adequately protect human health, safety, and welfare and the environment. Included in these rules as well as the regulations for underground storage tanks at 18 AAC 78, is the requirement for ensuring that contaminants at a site do not exceed cumulative risk thresholds for carcinogenic and noncarcinogenic compounds, accounting for exposure to multiple contaminants across multiple pathways. This document describes the procedures for calculating that cumulative risk.

Under 18 AAC 75.325(g) or 18 AAC 78.600(d), a responsible party must ensure that contaminants remaining onsite do not exceed the cumulative risk standard of 1 in 100,000 excess lifetime cancer risk across all exposure pathways for carcinogens and a hazard index of not more than one, reported to one significant figure, across all exposure pathways for noncarcinogens, regardless of whether the cleanup levels established for the site are under method two, three, or four.

ADEC utilizes a sum-of-ratios approach for calculating cumulative risk. The approach is carried out in two separate calculations; one calculation for carcinogenic effects and one for noncarcinogenic effects. Separating risk quantification in this way is necessary due to differences between the two types of effects. For carcinogens, risk is evaluated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (USEPA, 1989).

Within the carcinogenic category additional adjustments are incorporated if the chemical is considered to have a mutagenic mode of action. For noncarcinogens, risks are based on exposure over a threshold that is likely to be without effects. The calculations are then incorporated into a ratio approach and summed to quantify the cumulative risk. These procedures are for cumulative risk only and do not substitute for a baseline risk assessment.

Some compounds can cause both types of effects and are included in both cumulative risk calculations. For example, aldrin causes both carcinogenic and noncarcinogenic effects from soil exposure through the human health pathway. The cleanup level in Table B1 corresponds with the carcinogenic effect because it occurs at a lower concentration than does the noncarcinogenic effect.

1.1 Carcinogens

As stated in the preceding section, carcinogenic risk is estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a carcinogenic compound. Under 18 AAC 75.990(12), ADEC defines a carcinogen as "...a substance that meets the criteria of the descriptors "Carcinogenic to Humans" or "Likely to Be Carcinogenic to Humans" according to EPA's *Guidelines for Carcinogen Risk Assessment*, EPA/630/P-03/001F (USEPA, 2005).

Cumulative carcinogenic risk is the summation of all risks from each exposure pathway and exposure route. The cumulative carcinogenic risk equation is shown in Section 2.2. Unless demonstrated otherwise, cancer risks resulting from exposure to two or more carcinogens are

assumed to be additive. The cumulative carcinogenic risk equation assumes that there are no synergistic or antagonistic chemical interactions.

1.2 Mutagens

Some of the carcinogenic compounds listed in Tables B1 and C operate by a mutagenic mode of action for carcinogenesis. Some chemicals with a mutagenic mode of action, which would be expected to cause irreversible changes to DNA, are suspected to exhibit a greater effect in early-life versus later-life exposure. Cancer risk to children in the context of EPA's cancer guidelines (USEPA, 2005) includes both early-life exposures that may result in the occurrence of cancer during childhood and early-life exposures that may contribute to cancers later in life. In keeping with this guidance, mutagenic cancer risk is calculated separately, and the mutagen vinyl chloride and trichloroethylene has a unique set of equations. However, when calculating cumulative risk, mutagens are included with carcinogens. Consult the Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens, EPA/630/R-03/003F, March 2005 for further information.

1.3 Noncarcinogens

Under 18 AAC 75.990(69), ADEC defines a noncarcinogen as "...a hazardous substance with adverse health effects on humans other than cancer." The noncarcinogenic risk is represented by a hazard quotient (HQ), which is calculated from the ratio of estimated intake of a chemical to the estimated intake at which there are no observed adverse effects. The hazard index (HI) is the summation of all of the HQs for all pathways and exposure routes that affect the same target organ or system endpoint.

For noncarcinogens, the health threats resulting from exposure to two or more hazardous substances with similar types of toxic response are assumed to be additive. However, many noncarcinogens have varying toxic effects and therefore assuming that these effects are additive may not be valid. Noncarcinogenic compounds affect different target organs or systems by different mechanisms of toxicity. To accurately assess the possible effects of noncarcinogenic compounds, the HI can be segregated by target organ or system endpoint and mechanism of toxicity consistent with EPA's *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A) – Interim Final* (USEPA, 1989), *Guidelines for the Health Risk Assessment of Chemical Mixtures* (USEPA, 1986), and *Supplemental Guidance for Conducting Health Risk Assessment of Chemical Mixtures* (USEPA, 2000). Since the mechanism of toxicity is not well understood for many compounds, the department will evaluate segregation of the HI by target organ or system endpoint.

2.0 CALCULATING CUMULATIVE RISK

Cumulative risk is defined as the sum of risks resulting from multiple sources and pathways via which humans are exposed. When more than one hazardous substance is present at a site or multiple exposure pathways exist, the cleanup levels in Table B1 of 18 AAC 75.341 and Table C of 18 AAC 75.345 (hereinafter "Table B1"and "Table C") may need to be adjusted downward. The cumulative cancer risk remaining at the site when cleanup is completed must not exceed 1 in 100,000 (1×10^{-5}) unless otherwise approved by ADEC, and must not exceed the cumulative noncarcinogenic risk standard at a hazard index (HI) of one, reported to one significant figure.

1. When to Perform the Cumulative Risk Analysis

The cumulative risk standard must be met upon completion of site cleanup work, but the department advises that responsible parties be cognizant early on of potential cumulative risk issues to allow adjustments to the scope of the cleanup and avoid remobilization to the site post-cleanup. Therefore, it may be prudent to calculate cumulative risk as soon as adequate and representative data is available. The department does not require that gasoline, diesel and residual range petroleum hydrocarbon fractions (see both Table B2 of 18 AAC 75.341 and Table C) be included in cumulative risk calculations, since selected individual compounds from the fractions are accounted for in Table B1 and Table C. However the risk may be underestimated since each fraction can consist of several other compounds not accounted for. See section 5.6 for more information.

2. Procedures

The process for calculating cumulative risk is as follows:

1. Determine which compounds are considered chemicals of potential concern (COPCs) for inclusion in the calculation of cumulative risk. These chemicals will correspond to a HQ of 0.1 or cancer risk of 1×10^{-6} for the residential exposure scenario. COPCs can be determined using the maximum soil concentration of each contaminant at the site that exceeds $1/10^{th}$ of the human health levels in Table B1 for the applicable climate zone.[1] For groundwater, the maximum concentration is compared against $1/10^{th}$ of the cleanup levels in Table C (see Section 3.0 for addressing cumulative risk in groundwater). If no chemicals at the site exceed the 1/10th threshold for either media, or only petroleum range contamination is present, cumulative risk does not need to be calculated for the site. For help on how to evaluate compounds not listed in ADEC tables, see Section 5.4.

   Please note that some chemicals listed in Tables B1 and C are capped at saturation or solubility levels that are lower than the actual risk-based value. Using the 1/10th threshold may not adversely influence the calculation; however, adjustments may be needed for saturation or solubility-capped chemicals if several are COPCs at the site. The adjustments can be made to correspond to a HQ of 0.1 or cancer risk of 1×10^{-6} with ADEC cumulative risk tools. Please consult with ADEC staff for assistance in calculating the values.

2. When COPCs are present, develop a conceptual site model (CSM) that shows all of the complete exposure pathways at the site. A CSM should include the source of contamination, release/transport mechanisms, contact media (i.e. soil, air, or groundwater), exposure route (i.e., dermal contact, inhalation, ingestion) and receptor (i.e. current/future resident, subsistence user, or biota). For more information on developing a CSM, refer to the department's Guidance on Developing Conceptual Site Models (ADEC, 2017).

3. Using the worksheet example in Appendix A, record the following information for each contaminant:

   a) whether the contaminant is considered a carcinogen, noncarcinogen, or both (if it is a mutagen, record it as a carcinogen);
   b) the exposure media (soil, groundwater, air)

[1] 1/10 of the cleanup level corresponds to a HQ of 0.1 and cancer risk of 10E-6.

c) exposure route (ingestion, inhalation of volatiles and/or particulates, dermal contact)
d) maximum concentration or the mean soil concentration at the 95th percent upper confidence limit (UCL) remaining on-site following cleanup[2]; and
e) the corresponding risk-based concentration (RBC) in Appendix B for soil or groundwater.

RBCs correspond to the concentration in soil that would cause an adverse effect through the inhalation, ingestion, or dermal contact routes of exposure. RBCs are calculated using the equations presented in ADEC's PCCL 2016 and take into account default exposure and soil/aquifer data as well as toxicological data specific to the compound of interest. The RBCs differ from Table B1 and Table C in that individual exposure pathways are shown rather than individual exposure pathways are shown rather than the cumulative risk from the respective media listed in the Tables. Also, some cleanup levels in Table B1 are capped at the soil saturation concentration and therefore may equate to a lifetime cancer risk or HI that is lower than the department standard.

4. For each carcinogen, risk is calculated by dividing the maximum site concentration or the mean of the 95 UCL remaining on-site by the applicable RBC and multiplying by the risk management level of 1×10^{-5}. Cumulative carcinogenic risk is the summation of all the risks from each exposure pathway and exposure route. The equation is as follows:

$$Cumulative\ Carcinogenic\ Risk = \left[\left(\frac{conc_x}{RBC_x}\right) + \left(\frac{conc_y}{RBC_y}\right) + \left(\frac{conc_z}{RBC_z}\right) \ldots\right] \times 10^{-5}$$

5. For each noncarcinogen, the hazard quotient (HQ) is calculated by dividing the site concentration remaining on-site by the applicable RBC and multiplying by the risk management level of 1. The hazard index (HI) is the summation of all HQs across all pathways that are affecting the same target organ or system endpoint. The equation is as follows:

$$Hazard\ Index = \left[\left(\frac{conc_x}{RBC_x}\right) + \left(\frac{conc_y}{RBC_y}\right) + \left(\frac{conc_z}{RBC_z}\right) \ldots\right] \times 1$$

Soil cleanup levels through methods two and three address ingestion of soil, inhalation of volatile chemicals and chemical particulates from soil in outdoor ambient air, and dermal contact with soil. Cleanup levels for groundwater at Table C address ingestion of groundwater, dermal contact with groundwater, and inhalation of volatiles from groundwater.

All other pathways that are shown to be complete based on the site-specific CSM should be investigated. These include indoor air from vapor intrusion as well as consumption of wild foods or exposure as a result of other site uses. The vapor intrusion pathway can be addressed through a site-specific analysis following ADEC's Vapor Intrusion Guidance 2012, while other pathways can be addressed through a method four risk assessment.

[2] To employ the mean soil concentration at the 95% UCL under 18 AAC 75.380(c)(1), the department must approve an appropriate statistical method. As stated above, for groundwater, the site concentration is the maximum concentration, as described in 18 AAC 75.380(c)(2).

The RBCs for compounds not listed in Tables B1 and C and for compounds where alternative cleanup levels under method three are proposed, must be calculated on a site-specific basis using ADEC's Risk Assessment Procedures Manual (RAPM 2018).

3.0 CUMULATIVE RISK AND GROUNDWATER

Unless it is shown that the groundwater at the site is not used or could not potentially be used for human consumption, it should be assumed that these groundwater pathways are complete. Therefore, chemicals found in groundwater at one-tenth of the Table C values need to be included in the cumulative risk calculations.

Table C values were developed using ADEC's PCCL 2016. Levels developed using the risk-based equations in that document are based on an HQ of 1 or a lifetime excess cancer risk of 1×10^{-5} for ingestion of groundwater, inhalation of volatiles from groundwater and dermal contact with groundwater. The RBCs associated with the three groundwater exposure pathways can be found in Appendix B.

4.0 CUMULATIVE RISK UNDER METHOD FOUR

When conducting a method four risk assessment, compounds found at levels that correspond to greater than the risk based benchmarks of 1×10^{-6} risk or HQ of 0.1 will be retained for further analysis and are therefore included in the cumulative risk calculations. See ADEC's RAPM 2015 for more information.

5.0 CHEMICALS WITH SPECIAL CONSIDERATIONS

The following sections detail procedures for incorporating PCBs, dioxins, and lead in cumulative risk calculations. For additional information and assistance with these compounds please contact ADEC's risk assessor.

5.1 PCBs

Polychlorinated biphenyls (PCBs) are included in cumulative risk calculations although the cleanup levels are determined on a site-specific basis, based on land use, or through a site-specific risk assessment. If separate congener or Aroclor concentrations are present, the appropriate toxicological data can be used to calculate cancer risk. At the time of this document, EPA's *Integrated Risk Information System* (IRIS) had individual assessments for seven different Aroclors: 1016, 1221, 1232, 1242, 1248, 1254 and 1260.[3] In addition IRIS has individual assessments for a handful of specific congeners. If PCBs are presented as a total concentration, the most conservative cancer slope factor and reference dose should be used.

5.2 Dioxins

Risks from dioxins are calculated based on a 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalent (TEQ) approach and should be included in cumulative risk calculations. Toxicity

[3] Available at: http://www.epa.gov/IRIS/

equivalency factors (TEFs) are used to compare the relative toxicity of individual dioxin-like compounds to the more toxic TCDD. Included in this calculation are dioxins, furans, and dioxin-like PCBs. The TEQ approach is based on the assumption that dioxin and dioxin-like compounds act through the same mechanism of toxicity. The TEF for TCDD is equal to one, whereas the TEF values for all other dioxins and dioxin-like compounds are equal to less than one. The TEQ is defined as the product of the concentration of an individual dioxin-like compound (Ci) and the corresponding TEF for that compound (TEFi). The total TEQ is the sum of the TEQ for each of the congeners in a given mixture.

$$Total\ TEQ = \sum(Ci \times TEFi)$$

Once the total TEQ is calculated, this value can be compared to the dioxin slope factor and the risk can be calculated. The most current toxicological data and TEFs should be used when calculating risk to dioxins. The World Health Organization remains the leading recommended approach for TEFs.[4]

5.3 Lead

Lead contamination in soil or groundwater is not included in cumulative risk calculations. EPA found it inappropriate to apply a reference dose or cancer slope factor to lead (IRIS, 1988). The residential lead soil cleanup level in Table B1 is based on the Integrated Exposure Uptake Biokinetic (IEUBK) model. Soil cleanup levels for lead are site-specific, based on land use, and groundwater cleanup levels are presented in Table C. In addition, an alternative cleanup level may be proposed under a site-specific risk assessment.

Lead cleanup levels are based on land use; for residential land use, the soil cleanup level is 400 mg/kg. For commercial or industrial land use as applied in 18 AAC 75.340(e)(3), the soil cleanup level is 800 mg/kg. As part of a site-specific risk assessment conducted according to the RAPM 2015, approved exposure models may be used to evaluate exposure to a child resident or an adult worker. A responsible person may also propose an alternative cleanup level based on a chemical speciation of the lead present at the site, under a site-specific risk assessment. For soils contaminated with lead more than 15 feet below ground surface, lead cleanup levels will be determined on a site-specific basis.

5.4 Chemicals Not Found in ADEC Tables

To evaluate cumulative risk from a chemical for which no ADEC regulatory criteria is available, the first step is to consult the EPA Regional Screening Levels (RSL) table (available at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm) and compare the site concentration with the listed screening level for residential receptors. If it exceeds the value listed, which equates to a noncarcinogenic risk at HQ= 0.1 and cancer risk at 1×10^{-6} then consult with ADEC staff to calculate a method two cleanup level using the process outlined in the RAPM 2015. Toxicity and chemical data specific to the compound of concern will be needed. Toxicity data can be obtained from EPA's IRIS, EPA's *Provisional Peer Reviewed Toxicity*

[4] World Health Organization. 2005. International Programme on Chemical Safety, Toxicity equivalent factors for dioxins, furans, and dioxin-like PCBs. Available at: http://www.who.int/ipcs/assessment/tef_values.pdf

Values (PPRTVs)[5], or another accepted source (see Appendix C). Chemical data can be obtained from an accepted chemistry source such as the Risk Assessment Information System (RAIS).[6] When compounds are not listed in ADEC and RSL tables please consult with ADEC staff.

Next, if the highest concentration remaining in soil or groundwater exceeds $1/10^{th}$ of the calculated value, proceed with the steps as described in Section 2.2 of these procedures, including evaluating complete exposure pathways and comparing with the route-specific RBC(s) developed as part of the cleanup criteria calculations and validated by ADEC.

5.5 Naturally Occurring Compounds

DEC recommends the use of the U.S. Environmental Protection Agency's Guidance for Comparing Background and Chemical Concentrations in Soil for Comprehensive Environmental Response Compensation and Liability Act (CERCLA) Sites (USEPA, 2002), for determining if compounds found on site are attributable to background levels. If a chemical found at the site is shown to be solely attributable to naturally occurring background concentrations, then the chemical is not included in the cumulative risk calculations.

[5] Available at: http://hhpprtv.ornl.gov/

[6] Available at: http://rais.ornl.gov/

5.6 Petroleum Hydrocarbons

Each petroleum fraction is a mixture of many different chemicals. The Total Petroleum Hydrocarbon Criteria Working Group identified indicator contaminants to represent the toxicity of the petroleum fractions. Individual risks for each petroleum fraction are then calculated based on these indicator compounds (listed in the table below). In order to accomplish this, analytical data for these compounds must be collected at sites with petroleum contamination. If these indicator compounds are not present at greater than 1/10 of the cleanup level in Tables B1 and C, then no further assessment of cumulative risk is required; however site cleanup levels for petroleum fractions still must be met.

INDICATOR COMPOUNDS FOR PETROLEUM CONTAMINATED SITES

Volatiles (BTEX)	Metals as required on a case by case basis
Benzene*	Arsenic*
Toluene	Barium
Ethylbenzene*	Cadmium
Total xylenes	Chromium*†
	Lead
Polynuclear Aromatic Hydrocarbons (PAHs)	Nickel
-	Vanadium
Acenaphthene	
Acenaphthylene	Others as needed on a case by case basis
Anthracene	Ethylene dibromide (EDB)*
Benzo(a)anthracene*	1,2-dichloroethane (EDC)*
Benzo(b)fluroranthene*	Methyl tert-butyl ether (MTBE)*
Benzo(k)fluoranthene*	Volatile organic compounds (VOCs)*
Benzo(g,h,i)perylene	
Benzo(a)pyrene*	
Chrysene *	
Dibenzo(a,h)anthracene*	
Fluoranthene	
Fluorene	
Indeno(1,2,3-cd)pyrene*	
Naphthalene*	
Phenanthrene	
Pyrene	

* indicates carcinogenic

† Chromium includes both III and VI valances, but only VI is carcinogenic.

The carcinogenic risk of petroleum can be adequately evaluated by determining the risk from carcinogenic indicator compounds. Using the same rationale, noncarcinogenic effects of petroleum can be evaluated by calculating the HI for the indicator contaminants listed in Tables B1 and C. Therefore, the department believes that calculating cumulative risk for the indicator contaminants, in

addition to other contaminants on-site, is protective of the cumulative risk to petroleum exposure, provided that site cleanup levels for the petroleum fractions are also met.

The department understands that there are petroleum constituents that will not be captured using this method. For many of these constituents the toxicity of the compounds has not yet been determined or there is minimal risk due to exposure. Petroleum is a chemical mixture. Under the *Guidelines for the Health Risk Assessment of Chemical Mixtures* (USEPA, 1986), the most preferred method for evaluating the risk to chemical mixtures is to use toxicological data for the mixture itself. Many mixtures have different toxicological properties than their constituents. The best available method for assessing risk to petroleum mixtures is to use a surrogate approach to determine cumulative risk. This is done by developing reference doses for each carbon range and then summing the HQs to produce the HI as explained in the PCCL 2016. However, at this time, there is not enough toxicological data available to calculate risk from the full petroleum fractions. Mixtures in petroleum fractions vary by product type and refining process and are altered further by weathering in the environment.

In light of this level of uncertainty, the PCCL 2016 attempts to compensate for the unknown risk from the six aromatic and aliphatic fractions by adopting conservative percentages for the composition of each fraction within each petroleum range (gasoline range organics, diesel range organics, and residual range organics); therefore the fractions are not included in the cumulative risk calculations where the petroleum indicator compounds are used. See Section 6.10 of the PCCL 2016 for more information. The department continues to investigate this issue with the goal of decreasing the uncertainty for risk with a scientifically accurate approach to quantifying the full risk from the petroleum fractions.

6.0 CUMULATIVE RISK CALCULATIONS FOR METHOD THREE

If alternative cleanup levels have been developed under method three, the carcinogenic risk or HQ from each constituent and the cumulative risk are calculated in the same fashion as described in Section 2.2. The site concentration following cleanup is divided by the RBC and the quotient is multiplied by the target risk standard. When using method three cleanup levels with site-specific data, the RBCs in Appendix B cannot be used; instead the same site-specific parameters must be used to produce the method three RBCs. See ADEC's PCCL 2016.

7.0 ADDITIONAL PATHWAYS TO INVESTIGATE

Upon completion of the CSM evaluation, exposure pathways other than those accounted for in Tables B1, B2 and C may be found to be complete. Such exposure pathways may include the indoor air vapor pathway, consumption of cultivated or wild foods at the site, and exposures based on recreational use. Vapor intrusion may be addressed through a site-specific analysis using ADEC's Vapor Intrusion Guidance (2012), while other pathways will require a method four risk assessment. Tables B1, B2 and C include the following exposure routes for soil: dermal contact, ingestion, and inhalation of volatiles and particulates from ambient air; and include the following exposure routes for groundwater: dermal contact, ingestion, and inhalation of volatiles. All completed pathways must be included in cumulative risk calculations including those pathways not addressed in Tables B1 and C.

8.0 ROUNDING IN CUMULATIVE RISK

Under 18 AAC 75.325(g) or 18 AAC 78.600(d), a responsible person must ensure that, after completing site cleanup using methods two or three, the risk from hazardous substances does not exceed a cumulative carcinogenic risk standard of 1 in 100,000 across all exposure pathways and a cumulative noncarcinogenic risk standard at a hazard index of 1, rounded to one significant figure, for all exposure pathways. Similarly, under 18 AAC 75.325(h), a responsible person proposing an alternative cleanup level for soil or groundwater based on a site-specific risk assessment under method four must ensure that the risk from hazardous substances does not exceed the cumulative carcinogenic risk standard of 1 in 100,000 across all exposure pathways and the cumulative noncarcinogenic risk standard at a hazard index of 1 for all exposure pathways.

Both cumulative risk summations for the incremental lifetime cancer risk and the HI should be expressed using one significant figure. The risk for an individual exposure pathway for a chemical, either the cancer risk or the hazard quotient should be shown to two significant figures. These then would be rounded to one significant figure after calculating the cumulative risk.

Standard rounding procedures must be adhered to such that:

Starting from the left most significant digit, move to the right until you have as many digits as you are allowed to keep. Then look to the immediate right and note the number present. If the number to the right is a 5, 6, 7, 8, or 9, round the last significant digit up one. If the number to the right is a 4, 3, 2, 1, or 0, keep the last significant digit the same. Therefore, the rounding procedures and cumulative risk standards are consistent between methods two, three, and four.

9.0 ECOLOGICAL RECEPTORS

The noncarcinogenic HI is calculated for ecological receptors. The ecological noncarcinogenic risk management level is set at a HI of 1. Carcinogens are not considered to be of concern for ecological receptors. The HI is the sum of HQs across multiple exposure routes and exposure pathways. The HQ is calculated by dividing the dose by a risk-based ecological benchmark.

$$HI = \Sigma\, Dose \div Benchmark$$

If the HI exceeds 1, the individual HQs should be retained for further evaluation. See ADEC's RAPM 2015 for additional information.

REFERENCES

Alaska Department of Environmental Conservation (ADEC). 2002. Oil and Hazardous Substances Pollution Control Regulations 18AAC 75, Articles 3 and 9.

ADEC. 2018. Procedures for Calculating Cleanup Levels. Contaminated Sites Program.

ADEC. 2018. *Risk Assessment Procedures Manual.* Contaminated Sites Program.

ADEC. 2017. Guidance on Developing Conceptual Site Models. Contaminated Sites Program

Total Petroleum Hydrocarbon Criteria Working Group. 1997. Volume 4, Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH). Amherst Scientific Publishers, Amherst, MA.

United States Environmental Protection Agency (USEPA). March 2005 Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. EPA/630/R-03/003F. Risk Assessment Forum, Washington, DC.

United States Environmental Protection Agency (USEPA). 1997. *Health Effects Assessment Summary Tables: FY 1997 Update.* EPA/540/R-97-036. Office of Emergency and Remedial Response, Washington, DC.

USEPA. 1996. *Soil Screening Guidance: Technical Background Document.* EPA/540/R-95/128. Office of Solid Waste and Emergency Response, Washington, DC.

USEPA. 1996. *Soil Screening Guidance: User's Guide.* 9355.4-23. Office of Solid Waste and Emergency Response, Washington DC.

USEPA. 1989. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A).* EPA/540/1-89/002. Office of Emergency and Remedial Response, Washington, DC.

USEPA. 1988. Integrated Risk Information System: Lead and Compounds (Inorganic). http://www.epa.gov/iris/subst/0277.htm. Office of Research and Development, Washington, DC.

USEPA. 1986. *Guidelines for the Health Risk Assessment of Chemical Mixtures.* EPA/630/R-98/002. Office of Research and Development, Washington, DC.

APPENDIX A: WORKSHEET FOR CALCULATING CUMULATIVE RISK

Chemicals of Concern Carcinogens	Exposure Media	Exposure Route	Site Concentration(mg/kg, mg/L or mg/m³)	RBC	Conc÷RBC
Cumulative Carcinogenic Risk $= \left[\left(\frac{conc_x}{RBC_x}\right) + \left(\frac{conc_y}{RBC_y}\right) + \left(\frac{conc_z}{RBC_z}\right) \ldots\right] \times 10^{-5}$			Σ (Conc÷RBC) $\times 10^{-5}$		Total
Chemicals of Concern Noncarcinogens	Exposure Media	Exposure Route	Site Concentration(mg/kg, mg/L or mg/m³)	RBC	Conc÷RBC
Cumulative Noncarcinogenic Risk $= \left[\left(\frac{conc_x}{RBC_x}\right) + \left(\frac{conc_y}{RBC_y}\right) + \left(\frac{conc_z}{RBC_z}\right) \ldots\right] \times 1$			Σ (Conc÷RBC) X 1		Total

mg/kg = milligrams per kilogram
mg/L – milligrams per liter
RBC = risk based concentration

_____ Site Name

APPENDIX B: RESIDENTIAL HUMAN HEALTH RISK BASED CONCENTRATIONS

SOIL ARCTIC ZONE

SOIL ARCTIC ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Acenaphthene	83-32-9	No	8210	26600	-	-	-	-
Acenaphthylene	208-96-8	No	4110	13300	-	-	-	-
Acetone	67-64-1	No	123000	-	1.09×10^6	-	-	-
Aldrin	309-00-2	No	4.11	-	-	0.716	-	10.5
Perchlorate and Perchlorate Salts	14797-73-0	No	95.8	-	-	-	-	-
Anthracene	120-12-7	No	41100	133000	-	-	-	-
Antimony (metallic)	7440-36-0	No	54.8	-	-	-	-	-
Arsenic, Inorganic	7440-38-2	No	68.4	577	7390	13.5	96.1	3080
Barium	7440-39-3	No	27400	-	246000	-	-	-
Benz[a]anthracene	56-55-3	Yes	-	-	-	26.8	80.3	788
Benzaldehyde	100-52-7	No	13700	-	-	3040	-	-
Benzene	71-43-2	No	548	-	154	221	-	17.7
Benzo[a]pyrene	50-32-8	Yes	41.1	133	985	2.68	8.03	7980
Benzo[b]fluoranthene	205-99-2	Yes	-	-	-	26.8	80.3	79800
Benzo[g,h,i]perylene	191-24-2	No	4110	13300	-	-	-	-
Benzo[k]fluoranthene	207-08-9	Yes	-	-	-	268	803	798000
Benzoic Acid	65-85-0	No	548000	2.31×10^6	-	-	-	-
Benzyl Alcohol	100-51-6	No	13700	57700	-	-	-	-
Beryllium and compounds	7440-41-7	No	274	-	9850	-	-	5530
Bis(2-chloroethyl)ether	111-44-4	No	-	-	-	11.1	-	6.36
Bis(2-ethylhexyl)phthalate	117-81-7	No	2740	11500	-	869	3090	5530000
Bromobenzene	108-86-1	No	1100	-	659	-	-	-
Bromodichloromethane	75-27-4	No	2740	-	-	196	-	5.47
Bromoform	75-25-2	No	2740	-	-	1540	-	439
Bromomethane	74-83-9	No	192	-	16.2	-	-	-
Butadiene, 1,3-	106-99-0	No	-	-	4.18	3.58	-	1.87
Butanol, N-	71-36-3	No	13700	-	-	-	-	-
Butyl Benzyl Phthlate	85-68-7	No	27400	115000	-	6400	22800	-
Butylbenzene, n-	104-51-8	No	6840	-	-	-	-	-
Butylbenzene, sec-	135-98-8	No	13700	-	-	-	-	-
Butylbenzene, tert-	98-06-6	No	13700	-	-	-	-	-
Cadmium (Diet)	7440-43-9	No	137	1440	4930	-	-	7370

SOIL ARCTIC ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Carbon Disulfide	75-15-0	No	13700	-	1840	-	-	-
Carbon Tetrachloride	56-23-5	No	548		321	174		14.4
Chlordane	12789-03-6	No	68.4	721	1190	34.8	309	457
Chlordecone (Kepone)	143-50-0	No	41.1	173		1.22	4.32	2880
Chloroaniline, p-	106-47-8	No	548	2310	-	60.8	216	-
Chlorobenzene	108-90-7	No	2740		426			
Chloroform	67-66-3	No	1370	-	496	392	-	5.94
Chloromethane	74-87-3	No			247			
Chloronaphthalene, Beta-	91-58-7	No	11000	35500	-	-	-	-
Chlorophenol, 2-	95-57-8	No	684					
Chromium(III), Insoluble Salts	16065-83-1	No	205000	-	-	-	-	-
Chromium(VI)	18540-29-9	Yes	411		49300	5.36		57
Chromium, Total	7440-47-3	No	205000	-	-	-	-	-
Chrysene	218-01-9	Yes				2680	8030	7980000
Copper	7440-50-8	No	5480	-	-	-	-	-
Cresol, m-	108-39-4	No	6840	28800	296000000			
Cresol, o-	95-48-7	No	6840	28800	296000000	-	-	-
Cresol, p-	106-44-5	No	13700	57700	296000000			
Cumene	98-82-8	No	13700	-	3050	-	-	-
Cyanide (CN-)[5]	57-12-5	No	82.1		116			
Cyclohexane	110-82-7	No	-	-	13800	-	-	-
DDD	72-54-8	No	4.11	17.3		50.7	180	192000
DDE, p,p'-	72-55-9	No	41.1	-	-	35.8	-	647
DDT	50-29-3	No	68.4	961		35.8	424	137000
Dibenz[a,h]anthracene	53-70-3	Yes	-	-	-	2.68	8.03	7980
Dibenzofuran	132-64-9	No	137	1920				
Dibromochloromethane	124-48-1	No	2740	-	-	145	-	-
Dibromoethane, 1,2-	106-93-4	No	1230		138	6.08		0.687
Dibromomethane (Methylene Bromide)	74-95-3	No	-	-	45.3	-	-	-
Dibutyl Phthalate	84-74-2	No	13700	57700				
Dichlorobenzene, 1,2-	95-50-1	No	12300	-	2890	-	-	-
Dichlorobenzene, 1,3-	541-73-1	No	12300		2480			
Dichlorobenzene, 1,4-	106-46-7	No	9580	-	10400	2250	-	31.8
Dichlorobenzidine, 3,3'-	91-94-1	No				27.0	96.1	39000

SOIL ARCTIC ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Dichlorodifluoromethane	75-71-8	No	27400	-	221	-	-	-
Dichloroethane, 1,1-	75-34-3	No	27400			2130		69.2
Dichloroethane, 1,2-	107-06-2	No	821	-	57.2	134	-	8.46
Dichloroethylene, 1,1-	75-35-4	No	6840		519			
Dichloroethylene, 1,2-cis-	156-59-2	No	274	-	-	-	-	-
Dichloroethylene, 1,2-trans-	156-60-5	No	2740					
Dichlorophenol, 2,4-	120-83-2	No	411	1730	-	-	-	-
Dichlorophenoxy Acetic Acid, 2,4-	94-75-7	No	1370	11500				
Dichloropropane, 1,2-	78-87-5	No	5480	-	25.3	329	-	46.1
Dichloropropene, 1,3-	542-75-6	No	4110	-	116	122	-	38.9
Dieldrin	60-57-1	No	6.84	28.8	-	0.760	2.70	2880
Diethyl Phthalate	84-66-2	No	110000	461000				
Dimethylphenol, 2,4-	105-67-9	No	2740	11500	-	-	-	-
Dimethylphthalate	131-11-3	No	110000	461000				
Dinitrobenzene, 1,2-	528-29-0	No	13.7	57.7	-	-	-	-
Dinitrobenzene, 1,3-	99-65-0	No	13.7	57.7				
Dinitrobenzene, 1,4-	100-25-4	No	13.7	57.7	-	-	-	-
Dinitrophenol, 2,4-	51-28-5	No	274	1150				
Dinitrotoluene, 2,4-	121-14-2	No	274	1130	-	39.2	137	149000
Dinitrotoluene, 2,6-	606-20-2	No	41.1	175	-	8.11	29.1	
Dinitrotoluene, 2-Amino-4,6-	35572-78-2	No	274	19200	-	-	-	-
Dinitrotoluene, 4-Amino-2,6-	19406-51-0	No	274	12800				
Dioxane, 1,4-	123-91-1	No	4110	-	3050	122	-	548
Diphenylamine	122-39-4	No	13700	57700				
Endosulfan	115-29-7	No	821	-	-	-	-	-
Endrin	72-20-8	No	41.1	173				
Ethyl Chloride	75-00-3	No	-	-	28600	-	-	
Ethylbenzene	100-41-4	No	13700		7150	1110		77
Ethylene Glycol	107-21-1	No	274000	1.15×10^6	197000000	-	-	-
Fluoranthene	206-44-0	No	5480	17700				
Fluorene	86-73-7	No	5480	17700	-	-	-	-
Formaldehyde	50-00-0	No	27400		2030			428
Heptachlor	76-44-8	No	68.4	-	-	2.70	-	11.0
Heptachlor Epoxide	1024-57-3	No	1.78		-	1.34	-	9.74
Hexachlorobenzene	118-74-1	No	110	-	-	7.60	-	4.46

SOIL ARCTIC ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[1]	Inhalation[1]	Ingestion[2]	Dermal[3]	Inhalation[1]
Hexachlorobutadiene	87-68-3	No	137			156		15.9
Hexachlorocyclohexane, Alpha-	319-84-6	No	1100	4610	-	1.93	6.86	7370
Hexachlorocyclohexane, Beta-	319-85-7	No				6.76	24.0	25000
Hexachlorocyclohexane, Gamma- (Lindane)	58-89-9	No	41.1	433	-	11.1	98.3	42800
Hexachlorocyclopentadiene	77-47-4	No	821		2.06			
Hexachloroethane	67-72-1	No	95.8	-	327	304	-	26.7
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	No	411	11500		111	2620	
Hexane, N-	110-54-3	No	-	-	1550	-	-	-
Hexanone, 2-	591-78-6	No	684		848			
Hydrazine	302-01-2	No	-	-	5.09	4.06	-	0.931
Indeno[1,2,3-cd]pyrene	193-39-5	Yes				26.8	80.3	79800
Isophorone	78-59-1	No	27400	115000	985000000	12800	45500	-
Isopropanol	67-63-0	No	274000		14600			
Manganese, Total	7439-96-5	No	32900	-	24600	-	-	-
Mercuric Chloride	7487-94-7	No	41.1		148000			
Mercury (elemental)	7439-97-6	No	21.9	-	28.4	-	-	-
Methanol	67-56-1	No	274000		1.54 x 10[6]			
Methoxychlor	72-43-5	No	684	2880	-	-	-	-
Methyl Ethyl Ketone (2-Butanone)	78-93-3	No	82100		151000			
Methyl Isobutyl Ketone (4-methyl-2-pentanone)	108-10-1	No	-	-	69400	-	-	-
Methyl Mercury	22967-92-6	No	13.7					
Methyl tert-Butyl Ether (MTBE)	1634-04-4	No	-	-	32800	6760	-	1130
Methylene Chloride	75-09-2	Yes	821		2720	1340		4410
Methylnaphthalene, 1-	90-12-0	No	9580	31100	-	420	1150	-
Methylnaphthalene, 2-	91-57-6	No	548	1770				
Naphthalene	91-20-3	No	2740	8870	159	-	-	42
Nickel Soluble Salts	7440-02-0	No	2740		44300			51000
Nitrobenzene	98-95-3	No	274	-	850	-	-	63.6
Nitroglycerin	55-63-0	No	13.7	57.7		716	2540	
Nitroguanidine	556-88-7	No	13700	57700	-	-	-	-
Nitrosodimethylamine, N-	62-75-9	Yes	1.10		6.47	0.0526		0.112
Nitroso-di-N-propylamine, N-	621-64-7	No	-	-	-	1.74	6.18	6630

SOIL ARCTIC ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic[2]	Ingestion[3]	Dermal[3]	Inhalation[4]	Ingestion[3]	Dermal[3]	Inhalation[4]
Nitrosodiphenylamine, N-	86-30-6	No				2480	8830	5100000
Nitrotoluene, m-	99-08-1	No	13.7	57.7	-	-	-	-
Nitrotoluene, o-	88-72-2	No	123			55.3		
Nitrotoluene, p-	99-99-0	No	548	2310		760	2700	
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	2691-41-0	No	6840	481000				
Octyl Phthalate, di-N-	117-84-0	No	1370	5770	-	-	-	
Pentachlorophenol	87-86-5	No	684	1150		30.4	43.2	2600000
Pentaerythritol tetranitrate (PETN)	78-11-5	No	274	1150	-	3040	10800	-
Perfluorooctane Sulfonic acid (PFOS)[5]	1763-23-1	No	2.74	11.5	-	-	-	-
Perfluorooctanoic Acid (PFOA)	335-67-1	No	2.74	11.5	-	174	618	-
Phenanthrene	85-01-8	No	4110	13300	-	-	-	-
Phenol	108-95-2	No	41100	173000	98500000	-	-	-
Phosphorus, White	7723-14-0	No	2.74	-	-	-	-	-
Polychlorinated Biphenyls	1336-36-3	No	-	-	-	6.08	15.4	27.9
Propyl benzene	103-65-1	No	13700	-	8450	-	-	-
Pyrene	129-00-0	No	4110	13300	-	-	-	-
Selenium	7782-49-2	No	684	-	9850000	-	-	-
Silver	7440-22-4	No	684	-	-	-	-	-
Strontium, Total	7440-24-6	No	82100	-	-	-	-	-
Styrene	100-42-5	No	27400	-	11500	-	-	-
TCDD, 2,3,7,8-	1746-01-6	No	0.0000958	0.00135	0.087	0.0000936	0.00111	0.00154
Tetrachloroethane, 1,1,1,2-	630-20-6	No	4110	-	-	468	-	32
Tetrachloroethane, 1,1,2,2-	79-34-5	No	2740	-	-	60.8	-	10.4
Tetrachloroethylene	127-18-4	No	821	-	164	5790	-	425
Tetryl (Trinitrophenylmethylnitramine)	479-45-8	No	274	177000	-	-	-	-
Thallium (Soluble Salts)	7440-28-0	No	1.37	-	-	-	-	-
Toluene	108-88-3	No	11000	-	29100	-	-	-
Toxaphene	8001-35-2	No	-	-	-	11.1	39.3	41500
Trichloro-1,2,2-trifluoroethane, 1,1,2-	76-13-1	No	4.11×10^{5}	-	158000	-	-	-
Trichlorobenzene, 1,2,3-	87-61-6	No	110	-	-	-	-	-
Trichlorobenzene, 1,2,4-	120-82-1	No	1370	-	68.8	420	-	-
Trichloroethane, 1,1,1-	71-55-6	No	274000	-	16800	-	-	-
Trichloroethane, 1,1,2-	79-00-5	No	548	-	2.35	213	-	19.7
Trichloroethylene	79-01-6	Yes	68.4	-	7.98	154	-	18.3

SOIL ARCTIC ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Trichlorofluoromethane	75-69-4	No	41100					
Trichlorophenol, 2,4,5-	95-95-4	No	13700	57700	-	-	-	-
Trichlorophenol, 2,4,6-	88-06-2	No	137	577		1110	3930	4280000
Trichlorophenoxyacetic Acid, 2,4,5-	93-76-5	No	1370	5770	-	-	-	-
Trichlorophenoxypropionic acid, -2,4,5	93-72-1	No	1100	4610				
Trichloropropane, 1,2,3-	96-18-4	Yes	548	-	6.73	0.0893	-	-
Trimethylbenzene, 1,2,4-	95-63-6	No	1370		577			
Trimethylbenzene, 1,3,5-	108-67-8	No	1370	-	488	-	-	-
Tri-n-butyltin	688-73-3	No	41.1					
Trinitrobenzene, 1,3,5-	99-35-4	No	4110	91100	-	-	-	-
Trinitrotoluene, 2,4,6-	118-96-7	No	68.4	901		406	4500	
Vanadium and Compounds	7440-62-2	No	690	-	49300	-	-	-
Vinyl Acetate	108-05-4	No	137000		2140			
Vinyl Chloride	75-01-4	Yes	411	-	227	0.981	-	2.35
Xylenes	1330-20-7	No	27400		731			
Zinc and Compounds	7440-66-6	No	41100	-	-	-	-	-

[1] "CAS Number" means the Chemical Abstract Service (CAS) registry number uniquely assigned to chemicals by the American Chemical Society and recorded in the CAS Registry System

[2] "Ingestion" means a potential pathway of exposure to hazardous substances through direct consumption of the soil.

[3] "Dermal" means a potential pathway of exposure to hazardous substances through physical contact with the soil

[4] "Inhalation" means a potential pathway to volatile organic hazardous substances in the soil through volatilization.

[5] Cyanide expressed as free, or physiologically available cyanide

[6] Perfluorooctane Sulfonic Acid includes both the acid and its salt.

SOIL UNDER 40 INCH ZONE

SOIL UNDER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Acenaphthene	83-32-9	No	6080	19700	-	-	-	-
Acenaphthylene	208-96-8	No	3040	9860	-	-	-	-
Acetone	67-64-1	No	91300	-	743000	-	-	-
Aldrin	309-00-2	No	3.04	-	-	0.530	-	7.15
Perchlorate and Perchlorate Salts	14797-73-0	No	71.0	-	-	-	-	-
Anthracene	120-12-7	No	30400	98600	-	-	-	-
Antimony (metallic)	7440-36-0	No	40.6	-	-	-	-	-
Arsenic, Inorganic	7440-38-2	No	30.7	427	27600	10.0	71.2	11500
Barium	7440-39-3	No	20300	-	919000	-	-	-
Benz[a]anthracene	56-55-3	Yes	-	-	-	19.9	59.5	542
Benzaldehyde	100-52-7	No	10100	-	-	2250	-	-
Benzene	71-43-2	No	406	-	105	164	-	12.1
Benzo[a]pyrene	50-32-8	Yes	30.4	98.6	3680	1.99	5.95	29800
Benzo[b]fluoranthene	205-99-2	Yes	-	-	-	19.9	59.5	298000
Benzo[g,h,i]perylene	191-24-2	No	3040	9860	-	-	-	-
Benzo[k]fluoranthene	207-08-9	Yes	-	-	-	199	595	2980000
Benzoic Acid	65-85-0	No	406000	1.71×10^6	-	-	-	-
Benzyl Alcohol	100-51-6	No	10100	42700	-	-	-	-
Beryllium and compounds	7440-41-7	No	203	-	36800	-	-	20600
Bis(2-chloroethyl)ether	111-44-4	No	-	-	-	8.19	-	4.33
Bis(2-ethylhexyl)phthalate	117-81-7	No	2030	8550	-	644	2290	2.06×10^7
Bromobenzene	108-86-1	No	811	-	430	-	-	-
Bromodichloromethane	75-27-4	No	2030	-	-	145	-	3.73
Bromoform	75-25-2	No	2030	-	-	1140	-	300
Bromomethane	74-83-9	No	142	-	11.0	-	-	-
Butadiene, 1,3-	106-99-0	No	-	-	2.85	2.65	-	1.28
Butanol, N-	71-36-3	No	10100	-	-	-	-	-
Butyl Benzyl Phthlate	85-68-7	No	20300	85500	-	4740	16900	-
Butylbenzene, n-	104-51-8	No	5070	-	-	-	-	-
Butylbenzene, sec-	135-98-8	No	10100	-	-	-	-	-
Butylbenzene, tert-	98-06-6	No	10100	-	-	-	-	-
Cadmium (Diet)	7440-43-9	No	101	1070	18400	-	-	27500

SOIL UNDER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Carbon Disulfide	75-15-0	No	10100	-	1250	-	-	-
Carbon Tetrachloride	56-23-5	No	406		219	129		9.81
Chlordane	12789-03-6	No	50.7	534	812	25.7	229	312
Chlordecone (Kepone)	143-50-0	No	30.4	128		0.901	3.20	10800
Chloroaniline, p-	106-47-8	No	406	1710	-	45.1	160	-
Chlorobenzene	108-90-7	No	2030		290			
Chloroform	67-66-3	No	1010	-	338	291	-	4.05
Chloromethane	74-87-3	No			168			
Chloronaphthalene, Beta-	91-58-7	No	8110	26300	-	-	-	-
Chlorophenol, 2-	95-57-8	No	507					
Chromium(III), Insoluble Salts	16065-83-1	No	152000	-	-	-	-	-
Chromium(VI)	18540-29-9	Yes	304		18400	3.97		213
Chrysene	218-01-9	Yes	-	-	-	1990	5950	29800000
Copper	7440-50-8	No	4060					
Cresol, m-	108-39-4	No	5070	21400	1.10×10^9	-	-	-
Cresol, o-	95-48-7	No	5070	21400	1.10×10^9			
Cresol, p-	106-44-5	No	10100	42700	1.10×10^9	-	-	-
Cumene	98-82-8	No	10100		2080			
Cyanide (CN-)[5]	57-12-5	No	60.8	-	79.3	-	-	-
Cyclohexane	110-82-7	No			9440			
DDD	72-54-8	No	3.04	12.8	-	37.6	133	717000
DDE, p,p'-	72-55-9	No	30.4			26.5		443
DDT	50-29-3	No	50.7	712	-	26.5	314	510000
Dibenz[a,h]anthracene	53-70-3	Yes				1.99	5.95	29800
Dibenzofuran	132-64-9	No	101	1420	-	-	-	-
Dibromochloromethane	124-48-1	No	2030			107		
Dibromoethane, 1,2-	106-93-4	No	913	-	94.0	4.51	-	0.468
Dibromomethane (Methylene Bromide)	74-95-3	No			30.9			
Dibutyl Phthalate	84-74-2	No	10100	42700	-	-	-	-
Dichlorobenzene, 1,2-	95-50-1	No	9130		1970			
Dichlorobenzene, 1,3-	541-73-1	No	9130	-	1690	-	-	-
Dichlorobenzene, 1,4-	106-46-7	No	7100		7090	1670		21.7
Dichlorobenzidine, 3,3'-	91-94-1	No	-	-	-	20.0	71.2	146000
Dichlorodifluoromethane	75-71-8	No	20300		150			

SOIL UNDER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Dichloroethane, 1,1-	75-34-3	No	20300	-	-	1580	-	47.2
Dichloroethane, 1,2-	107-06-2	No	608	-	39.0	99.0	-	5.77
Dichloroethylene, 1,1-	75-35-4	No	5070	-	354	-	-	-
Dichloroethylene, 1,2-cis-	156-59-2	No	203	-	-	-	-	-
Dichloroethylene, 1,2-trans-	156-60-5	No	2030	-	-	-	-	-
Dichlorophenol, 2,4-	120-83-2	No	304	1280	-	-	-	-
Dichlorophenoxy Acetic Acid, 2,4-	94-75-7	No	1010	8550	-	-	-	-
Dichloropropane, 1,2-	78-87-5	No	4060	-	17.3	244	-	31.4
Dichloropropene, 1,3-	542-75-6	No	3040	-	78.9	90.1	-	26.6
Dieldrin	60-57-1	No	5.07	21.4	-	0.563	2.00	10800
Diethyl Phthalate	84-66-2	No	81100	342000	-	-	-	-
Dimethylphenol, 2,4-	105-67-9	No	2030	8550	-	-	-	-
Dimethylphthalate[5]	131-11-3	No	81100	342000	-	-	-	-
Dinitrobenzene, 1,2-	528-29-0	No	10.1	42.7	-	-	-	-
Dinitrobenzene, 1,3-	99-65-0	No	10.1	42.7	-	-	-	-
Dinitrobenzene, 1,4-	100-25-4	No	10.1	42.7	-	-	-	-
Dinitrophenol, 2,4-	51-28-5	No	203	855	-	-	-	-
Dinitrotoluene, 2,4-	121-14-2	No	203	838	-	29.1	101	556000
Dinitrotoluene, 2,6-	606-20-2	No	30.4	129	-	6.01	21.6	-
Dinitrotoluene, 2-Amino-4,6-	35572-78-2	No	203	14200	-	-	-	-
Dinitrotoluene, 4-Amino-2,6-	19406-51-0	No	203	9490	-	-	-	-
Dioxane, 1,4-	123-91-1	No	3040	-	2080	90.1	-	374
Diphenylamine	122-39-4	No	10100	42700	-	-	-	-
Endosulfan	115-29-7	No	608	-	-	-	-	-
Endrin	72-20-8	No	30.4	128	-	-	-	-
Ethyl Chloride	75-00-3	No	-	-	19500	-	-	-
Ethylbenzene	100-41-4	No	10100	-	4870	819	-	52.5
Ethylene Glycol	107-21-1	No	203000	855000	7.35×10^5	-	-	-
Fluoranthene	206-44-0	No	4060	13100	-	-	-	-
Fluorene	86-73-7	No	4060	13100	-	-	-	-
Formaldehyde	50-00-0	No	20300	-	1390	-	-	292
Heptachlor	76-44-8	No	50.7	-	-	2.00	-	7.54
Heptachlor Epoxide	1024-57-3	No	1.32	-	-	0.990	-	6.65
Hexachlorobenzene	118-74-1	No	81.1	-	-	5.63	-	3.04
Hexachlorobutadiene	87-68-3	No	101	-	-	116	-	10.8

SOIL UNDER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic[2]	Ingestion[3]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Hexachlorocyclohexane, Alpha-	319-84-6	No	811	3420		1.43	5.08	27500
Hexachlorocyclohexane, Beta-	319-85-7	No	-	-	-	5.01	17.8	93400
Hexachlorocyclohexane, Gamma- (Lindane)	58-89-9	No	30.4	320		8.19	72.8	160000
Hexachlorocyclopentadiene	77-47-4	No	608	-	1.40	-	-	-
Hexachloroethane	67-72-1	No	71.0		223	225		18.2
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	No	304	8550	-	81.9	1940	-
Hexane, N-	110-54-3	No			1050			
Hexanone, 2-	591-78-6	No	507	-	578	-	-	-
Hydrazine	302-01-2	No			3.47	3.00		0.635
Indeno[1,2,3-cd]pyrene	193-39-5	Yes	-	-	-	19.9	59.5	298000
Isophorone	78-59-1	No	20300	85500	3.68×10^3	9490	33700	
Isopropanol	67-63-0	No	203000	-	9940	-	-	-
Manganese, Total	7439-96-5	No	2430		91900			
Mercuric Chloride	7487-94-7	No	30.4	-	552000	-	-	-
Mercury (elemental)	7439-97-6	No			19.4			
Methanol	67-56-1	No	203000	-	1.05×10^6	-	-	-
Methoxychlor	72-43-5	No	507	2140				
Methyl Ethyl Ketone (2-Butanone)	78-93-3	No	60800	-	103000	-	-	-
Methyl Isobutyl Ketone (4-methyl-2-pentanone)	108-10-1	No			47300			
Methyl Mercury	22967-92-6	No	10.1	-	-	-	-	-
Methyl tert-Butyl Ether (MTBE)	1634-04-4	No			22300	5010		771
Methylene Chloride	75-09-2	Yes	608	-	1850	993	-	3000
Methylnaphthalene, 1-	90-12-0	No	7100	23000		311	850	
Methylnaphthalene, 2-	91-57-6	No	406	1310	-	-	-	-
Naphthalene	91-20-3	No	2030	6570	108			28.6
Nickel Soluble Salts	7440-02-0	No	2030	-	165000	-	-	190000
Nitrobenzene	98-95-3	No	203		580			43.4
Nitroglycerin	55-63-0	No	10.1	42.7	-	530	1880	-
Nitroguanidine	556-88-7	No	10100	42700				
Nitrosodimethylamine, N-	62-75-9	Yes	0.811	-	4.41	0.0389	-	0.0766
Nitroso-di-N-propylamine, N-	621-64-7	No				1.29	4.58	24700
Nitrosodiphenylamine, N-	86-30-6	No	-	-	-	1840	6540	1.90×10^5

SOIL UNDER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Nitrotoluene, m-	99-08-1	No	10.1	42.7	-	-	-	-
Nitrotoluene, o-	88-72-2	No	91.3	-	-	41.0	-	-
Nitrotoluene, p-	99-99-0	No	406	1710	-	563	2000	-
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	2691-41-0	No	5070	356000	-	-	-	-
Octyl Phthalate, di-N-	117-84-0	No	1010	4270	-	-	-	-
Pentachlorophenol	87-86-5	No	507	855	-	22.5	32.0	9.71 x 10[5]
Pentaerythritol tetranitrate (PETN)	78-11-5	No	203	853	-	2250	8010	-
Perfluorooctane Sulfonic acid (PFOS)[6]	1763-23-1	No	2.03	8.55	-	-	-	-
Perfluorooctanoic Acid (PFOA)	335-67-1	No	2.03	8.55	-	129	458	-
Phenanthrene	85-01-8	No	3040	9860	-	-	-	-
Phenol	108-95-2	No	30400	128000	3.68x 10[5]	-	-	-
Phosphorus, White	7723-14-0	No	2.03	-	-	-	-	-
Polychlorinated Biphenyls	1336-36-3	No	-	-	-	4.51	11.4	19.0
Propyl benzene	103-65-1	No	10100	-	5760	-	-	-
Pyrene	129-00-0	No	3040	9860	-	-	-	-
Selenium	7782-49-2	No	507	-	3.68 x 10[5]	-	-	-
Silver	7440-22-4	No	507	-	-	-	-	-
Strontium, Total	7440-24-6	No	60800	-	-	-	-	-
Styrene	100-42-5	No	20300	-	7820	-	-	-
TCDD, 2,3,7,8-	1746-01-6	No	0.0000710	0.000097	0.0595	0.0000693	0.000821	0.00105
Tetrachloroethane, 1,1,1,2-	630-20-6	No	3040	-	-	347	-	21.8
Tetrachloroethane, 1,1,2,2-	79-34-5	No	2030	-	-	45.1	-	7.07
Tetrachloroethylene	127-18-4	No	608	-	112	4290	-	290
Tetryl (Trinitrophenylmethylnitramine)	479-45-8	No	203	131000	-	-	-	-
Thallium (Soluble Salts)	7440-28-0	No	1.01	-	-	-	-	-
Toluene	108-88-3	No	8110	-	19800	-	-	-
Toxaphene	8001-35-2	No	-	-	-	8.19	29.1	155000
Trichloro-1,2,2-trifluoroethane, 1,1,2-	76-13-1	No	3.04 x 10[5]	-	10800	-	-	-
Trichlorobenzene, 1,2,3-	87-61-6	No	81.1	-	-	-	-	-
Trichlorobenzene, 1,2,4-	120-82-1	No	1010	-	46.9	311	-	-
Trichloroethane, 1,1,1-	71-55-6	No	203000	-	11400	-	-	-

SOIL UNDER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Trichloroethane, 1,1,2-	79-00-5	No	406	-	1.60	158	-	13.5
Trichloroethylene	79-01-6	Yes	50.7		5.44	114		12.5
Trichlorofluoromethane	75-69-4	No	30400	-	-	-	-	-
Trichlorophenol, 2,4,5-	95-95-4	No	10100	42700				
Trichlorophenol, 2,4,6-	88-06-2	No	101	427	-	819	2910	1.60×10^{7}
Trichlorophenoxyacetic Acid, 2,4,5-	93-76-5	No	1010	4270				
Trichlorophenoxypropionic acid, - 2,4,5	93-72-1	No	811	3420	-	-	-	-
Trichloropropane, 1,2,3-	96-18-4	Yes	406		4.59	0.0662		
Trimethylbenzene, 1,2,4-	95-63-6	No	1010	-	394	-	-	-
Trimethylbenzene, 1,3,5-	108-67-8	No	1010		333	-		-
Tri-n-butyltin	688-73-3	No	30.4	-	-	-	-	-
Trinitrobenzene, 1,3,5-	99-35-4	No	3040	67500				
Trinitrotoluene, 2,4,6-	118-96-7	No	50.7	668	-	300	3340	-
Vanadium and Compounds	7440-62-2	No	511		184000			
Vinyl Acetate	108-05-4	No	101000	-	1460	-	-	-
Vinyl Chloride	75-01-4	Yes	304		155	0.962		2.04
Xylenes	1330-20-7	No	20300	-	498	-	-	-
Zinc and Compounds	7440-66-6	No	30400	-		-	-	

[1] "CAS Number" means the Chemical Abstract Service (CAS) registry number uniquely assigned to chemicals by the American Chemical Society and recorded in the CAS Registry System

[2] "Ingestion" means a potential pathway of exposure to hazardous substances through direct consumption of the soil.

[3] "Dermal" means a potential pathway of exposure to hazardous substances through physical contact with the soil

[4] "Inhalation" means a potential pathway to volatile organic hazardous substances in the soil through volatilization.

[5] Cyanide expressed as free, or physiologically available cyanide

[6] Perfluorooctane Sulfonic Acid includes both the acid and its salt.

SOIL OVER 40 INCH ZONE

SOIL OVER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Acenaphthene	83-32-9	No	4980	16100	-	-	-	-
Acenaphthylene	208-96-8	No	2490	8070	-	-	-	-
Acetone	67-64-1	No	74700	-	530000	-	-	-
Aldrin	309-00-2	No	2.49	-	-	0.434	-	5.10
Perchlorate and Perchlorate Salts	14797-73-0	No	58.1	-	-	-	-	-
Anthracene	120-12-7	No	24900	80700	-	-	-	-
Antimony (metallic)	7440-36-0	No	33.2	-	-	-	-	-
Arsenic, Inorganic	7440-38-2	No	41.5	350	94700	8.19	58.2	39500
Barium	7440-39-3	No	16600	-	3.16×10^{6}	-	-	-
Benz[a]anthracene	56-55-3	Yes	-	-	-	16.2	48.7	387
Benzaldehyde	100-52-7	No	8300	-	-	1840	-	-
Benzene	71-43-2	No	332	-	74.9	1.34	-	8.62
Benzo[a]pyrene	50-32-8	Yes	24.9	80.7	12600	1.62	4.87	102000
Benzo[b]fluoranthene	205-99-2	Yes	-	-	-	16.2	48.7	1020000
Benzo[g,h,i]perylene	191-24-2	No	2490	8070	-	-	-	-
Benzo[k]fluoranthene	207-08-9	Yes	-	-	-	162	487	10200000
Benzoic Acid	65-85-0	No	332000	1.40×10^{6}	-	-	-	-
Benzyl Alcohol	100-51-6	No	8300	35000	-	-	-	-
Beryllium and compounds	7440-41-7	No	166	-	126000	-	-	70800
Bis(2-chloroethyl)ether	111-44-4	No	-	-	-	6.70	-	3.09
Bis(2-ethylhexyl)phthalate	117-81-7	No	1660	6990	-	527	1870	7.08×10^{5}
Bromobenzene	108-86-1	No	664	-	321	-	-	-
Bromodichloromethane	75-27-4	No	1660	-	-	119	-	2.66
Bromoform	75-25-2	No	1660	-	-	933	-	214
Bromomethane	74-83-9	No	116	-	7.86	-	-	-
Butadiene, 1,3-	106-99-0	No	-	-	2.03	2.17	-	0.911
Butanol, N-	71-36-3	No	8300	-	-	-	-	-
Butyl Benzyl Phthlate	85-68-7	No	16600	69900	-	3880	13800	-
Butylbenzene, n-	104-51-8	No	4150	-	-	-	-	-
Butylbenzene, sec-	135-98-8	No	8300	-	-	-	-	-
Butylbenzene, tert-	98-06-6	No	8300	-	-	-	-	-
Cadmium (Diet)	7440-43-9	No	83.0	874	63200	-	-	94500

SOIL OVER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Carbon Disulfide	75-15-0	No	8300	-	894	-	-	-
Carbon Tetrachloride	56-23-5	No	332		156	105		7.00
Chlordane	12789-03-6	No	41.5	437	579	21.1	187	223
Chlordecone (Kepone)	143-50-0	No	24.9	105		0.737	2.62	37000
Chloroaniline, p-	106-47-8	No	332	1400	-	36.9	131	-
Chlorobenzene	108-90-7	No	1660		20[5]			
Chloroform	67-66-3	No	830	-	241	238	-	2.89
Chloromethane	74-87-3	No			120			-
Chloronaphthalene, Beta-	91-58-7	No	6640	21500	-	-	-	-
Chlorophenol, 2-	95-57-8	No	415					-
Chromium(III), Insoluble Salts	16065-83-1	No	124000	-	-	-	-	-
Chromium(VI)	18540-29-9	Yes	249		632000	3.25		731
Chrysene	218-01-9	Yes	-	-	-	1620	4870	102000000
Copper	7440-50-8	No	3320					-
Cresol, m-	108-39-4	No	4150	17500	3.79×10^9	-	-	-
Cresol, o-	95-48-7	No	4150	17500	3.79×10^9			-
Cresol, p-	106-44-5	No	8300	35000	3.79×10^9	-	-	-
Cumene	98-82-8	No	8300		1480			-
Cyanide (CN-)[5]	57-12-5	No	49.8	-	56.5	-	-	-
Cyclohexane	110-82-7	No			6730			
DDD	72-54-8	No	2.49	10.5	-	30.7	109	2.46×10^6
DDE, p,p'-	72-55-9	No	24.9			21.7		316
DDT	50-29-3	No	41.5	583	-	21.7	257	1.75×10^6
Dibenz[a,h]anthracene	53-70-3	Yes				1.62	4.87	102000
Dibenzofuran	132-64-9	No	83.0	1170	-	-	-	-
Dibromochloromethane	124-48-1	No	1660			87.8		-
Dibromoethane, 1,2-	106-93-4	No	747	-	67.0	3.69	-	0.334
Dibromomethane (Methylene Bromide)	74-95-3	No			22.0			
Dibutyl Phthalate	84-74-2	No	8300	35000	-	-	-	-
Dichlorobenzene, 1,2-	95-50-1	No	7470		1410			-
Dichlorobenzene, 1,3-	541-73-1	No	7470	-	1200	-	-	-
Dichlorobenzene, 1,4-	106-46-7	No	5810		5060	1370		15.5
Dichlorobenzidine, 3,3'-	91-94-1	No	-	-	-	16.4	58.2	500000
Dichlorodifluoromethane	75-71-8	No	16680		107			-

SOIL OVER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic[2]	Ingestion[3]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Dichloroethane, 1,1-	75-34-3	No	16600	-	-	1290	-	33.7
Dichloroethane, 1,2-	107-06-2	No	498	-	27.8	81.0	-	4.11
Dichloroethylene, 1,1-	75-35-4	No	4150	-	252	-	-	-
Dichloroethylene, 1,2-cis-	156-59-2	No	166	-	-	-	-	-
Dichloroethylene, 1,2-trans-	156-60-5	No	1660	-	-	-	-	-
Dichlorophenol, 2,4-	120-83-2	No	249	1050	-	-	-	-
Dichlorophenoxy Acetic Acid, 2,4-	94-75-7	No	830	6990	-	-	-	-
Dichloropropane, 1,2-	78-87-5	No	3320	-	12.3	199	-	22.4
Dichloropropene, 1,3-	542-75-6	No	2490	-	56.2	73.7	-	18.9
Dieldrin	60-57-1	No	4.15	17.5	-	0.461	1.64	37000
Diethyl Phthalate	84-66-2	No	66400	280000	-	-	-	-
Dimethylphenol, 2,4-	105-67-9	No	1660	6990	-	-	-	-
Dimethylphthalate	131-11-3	No	66400	280000	-	-	-	-
Dinitrobenzene, 1,2-	528-29-0	No	8.30	35.0	-	-	-	-
Dinitrobenzene, 1,3-	99-65-0	No	8.30	35.0	-	-	-	-
Dinitrobenzene, 1,4-	100-25-4	No	8.30	35.0	-	-	-	-
Dinitrophenol, 2,4-	51-28-5	No	166	699	-	-	-	-
Dinitrotoluene, 2,4-	121-14-2	No	166	685	-	23.8	82.9	1.91 x 10[5]
Dinitrotoluene, 2,6-	606-20-2	No	24.9	106	-	4.92	17.6	-
Dinitrotoluene, 2-Amino-4,6-	35572-78-2	No	166	11700	-	-	-	-
Dinitrotoluene, 4-Amino-2,6-	19406-51-0	No	166	7770	-	-	-	-
Dioxane, 1,4-	123-91-1	No	2490	-	1480	73.7	-	266
Diphenylamine	122-39-4	No	8301	35000	-	-	-	-
Endosulfan	115-29-7	No	498	-	-	-	-	-
Endrin	72-20-8	No	24.9	105	-	-	-	-
Ethyl Chloride	75-00-3	No	-	-	13900	-	-	-
Ethylbenzene	100-41-4	No	8300	-	3470	670	-	37.4
Ethylene Glycol	107-21-1	No	166000	699000	2.53 x 10[5]	-	-	-
Fluoranthene	206-44-0	No	3320	10800	-	-	-	-
Fluorene	86-73-7	No	3320	10800	-	-	-	-
Formaldehyde	50-00-0	No	16600	-	988	-	-	208
Heptachlor	76-44-8	No	41.5	-	-	1.64	-	5.38
Heptachlor Epoxide	1024-57-3	No	1.08	-	-	0.810	-	4.74
Hexachlorobenzene	118-74-1	No	66.4	-	-	4.61	-	2.17
Hexachlurobutadiene	87-68-3	No	83.0	-	-	94.5	-	7.73

SOIL OVER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Hexachlorocyclohexane, Alpha-	319-84-6	No	664	2800		1.17	4.16	94500
Hexachlorocyclohexane, Beta-	**319-85-7**	**No**	-	-	-	**4.10**	**14.6**	**321000**
Hexachlorocyclohexane, Gamma-(Lindane)	58-89-9	No	24.9	262		6.70	59.6	549000
Hexachlorocyclopentadiene	**77-47-4**	**No**	**498**	-	**1.00**	-	-	-
Hexachloroethane	67-72-1	No	58.1		159	184		13.0
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	**121-82-4**	**No**	**249**	**6990**	-	**67.0**	**1590**	-
Hexane, N-	110-54-3	No			752			
Hexanone, 2-	**591-78-6**	**No**	**415**	-	**412**	-	-	-
Hydrazine	302-01-2	No			2.47	2.46		0.453
Indeno[1,2,3-cd]pyrene	**193-39-5**	**Yes**	-	-	-	**16.2**	**48.7**	**1020000**
Isophorone	78-59-1	No	16600	69000	1.26×10^{5}	7760	27600	
Isopropanol	**67-63-0**	**No**	**166000**	-	**7080**	-	-	-
Manganese, Total	7439-96-5	No	1990		316000			
Mercuric Chloride	**7487-94-7**	**No**	**24.9**	-	**1.89×10^{6}**	-	-	-
Mercury (elemental)	7439-97-6	No			13.8			
Methanol	**67-56-1**	**No**	**166000**	-	**751000**	-	-	-
Methoxychlor	72-43-5	No	415	1750				
Methyl Ethyl Ketone (2-Butanone)	**78-93-3**	**No**	**49800**	-	**73300**	-	-	-
Methyl Isobutyl Ketone (4-methyl-2-pentanone)	108-10-1	No			33700			
Methyl Mercury	**22967-92-6**	**No**	**8.30**	-	-	-	-	-
Methyl tert-Butyl Ether (MTBE)	1634-04-4	No			15900	4100		550
Methylene Chloride	**75-09-2**	**Yes**	**498**	-	**1320**	**812**	-	**2140**
Methylnaphthalene, 1-	90-12-0	No	5810	18800		254	695	
Methylnaphthalene, 2-	**91-57-6**	**No**	**332**	**1080**	-	-	-	-
Naphthalene	91-20-3	No	1660	5380	77.3			20.4
Nickel Soluble Salts	**7440-02-0**	**No**	**1660**	-	**568000**	-	-	**654000**
Nitrobenzene	98-95-3	No	166		413			30.9
Nitroglycerin	**55-63-0**	**No**	**8.30**	**35.0**	-	**434**	**1540**	-
Nitroguanidine	556-88-7	No	8300	35000				
Nitrosodimethylamine, N-	**62-75-9**	**Yes**	**0.664**	-	**3.14**	**0.0318**	-	**0.0546**
Nitroso-di-N-propylamine, N-	621-64-7	No				1.05	3.74	85000
Nitrosodiphenylamine, N-	**86-30-6**	**No**	-	-	-	**1500**	**5350**	**6.54×10^{7}**

SOIL OVER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[3]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Nitrotoluene, m-	99-08-1	No	8.30	35.0				
Nitrotoluene, o-	88-72-2	No	74.7	-	-	33.5	-	-
Nitrotoluene, p-	99-99-0	No	332	1400	-	461	1640	-
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	2691-41-0	No	4150	291000	-	-	-	-
Octyl Phthalate, di-N-	117-84-0	No	830	3500				
Pentachlorophenol	87-86-5	No	415	699	-	18.4	26.2	3.33 x 10[7]
Pentaerythritol tetranitrate (PETN)	78-11-5	No	166	699	-	1840	6550	-
Perfluorooctane Sulfonic acid (PFOS)[6]	1763-23-1	No	1.66	6.99	-	-	-	-
Perfluorooctanoic Acid (PFOA)	335-67-1	No	1.66	6.99	-	105	374	-
Phenanthrene	85-01-8	No	2490	8070	-	-	-	-
Phenol	108-95-2	No	24900	105000	1.26 x 10[6]			
Phosphorus, White	7723-14-0	No	1.66	-	-	-	-	-
Polychlorinated Biphenyls	1336-36-3	No	-	-	-	3.69	9.36	13.6
Propyl benzene	103-65-1	No	8300	-	4110	-	-	-
Pyrene	129-00-0	No	2490	8070	-	-	-	-
Selenium	7782-49-2	No	415	-	1.26x 10[5]	-	-	-
Silver	7440-22-4	No	415	-	-	-	-	-
Strontium, Total	7440-24-6	No	49800	-	-	-	-	-
Styrene	100-42-5	No	16600	-	3580	-	-	-
TCDD, 2,3,7,8-	1746-01-6	No	0.0000581	0.000816	0.0425	0.0000567	0.000672	0.000752
Tetrachloroethane, 1,1,1,2-	630-20-6	No	2490	-	-	284	-	15.6
Tetrachloroethane, 1,1,2,2-	79-34-5	No	1660	-	-	36.9	-	5.04
Tetrachloroethylene	127-18-4	No	498	-	79.9	3510	-	207
Tetryl (Trinitrophenylmethylnitramine)	479-45-8	No	166	108000	-	-	-	-
Thallium (Soluble Salts)	7440-28-0	No	0.830	-	-	-	-	-
Toluene	108-88-3	No	6640	-	14100	-	-	-
Toxaphene	8001-35-2	No	-	-	-	6.70	23.8	531000
Trichloro-1,2,2-trifluoroethane, 1,1,2-	76-13-1	No	249 x 10[3]	-	7700	-	-	-
Trichlorobenzene, 1,2,3-	87-61-6	No	66.4	-	-	-	-	-
Trichlorobenzene, 1,2,4-	120-82-1	No	830	-	33.4	254	-	-
Trichloroethane, 1,1,1-	71-55-6	No	166000	-	8160	-	-	-

SOIL OVER 40 INCH ZONE			Non-Carcinogenic (mg/kg)			Carcinogenic (mg/kg)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Trichloroethane, 1,1,2-	79-00-5	No	332	-	1.14	129	-	9.59
Trichloroethylene	79-01-6	Yes	41.5		3.88	93.1		8.89
Trichlorofluoromethane	75-69-4	No	24900	-	-	-	-	-
Trichlorophenol, 2,4,5-	95-95-4	No	8300	35000				
Trichlorophenol, 2,4,6-	88-06-2	No	83.0	350	-	670	2380	5.49 x 10^{-5}
Trichlorophenoxyacetic Acid, 2,4,5-	93-76-5	No	830	3500				
Trichlorophenoxypropionic acid, - 2,4,5	93-72-1	No	664	2800	-	-	-	-
Trichloropropane, 1,2,3-	96-18-4	Yes	332		3.27	0.0541		
Trimethylbenzene, 1,2,4-	95-63-6	No	830	-	281	-	-	-
Trimethylbenzene, 1,3,5-	108-67-8	No	830		237			
Tri-n-butyltin	688-73-3	No	24.9	-	-	-	-	-
Trinitrobenzene, 1,3,5-	99-35-4	No	2490	55200				
Trinitrotoluene, 2,4,6-	118-96-7	No	41.5	546	-	246	2730	-
Vanadium and Compounds	7440-62-2	No	418		632000			
Vinyl Acetate	108-05-4	No	83000	-	1040	-	-	-
Vinyl Chloride	75-01-4	Yes	249		110	0.945		1.69
Xylenes	1330-20-7	No	16600	-	355	-	-	-
Zinc and Compounds	7440-66-6	No	24900					

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[3] "Dermal" means a potential pathway of exposure to hazardous substances through physical contact with the soil

[4] "Inhalation" means a potential pathway to volatile organic hazardous substances in the soil through volatilization.

[5] Cyanide expressed as free, or physiologically available cyanide

[6] Perfluorooctane Sulfonic Acid includes both the acid and its salt.

GROUNDWATER

GROUNDWATER			Non-Carcinogenic (µg/L)			Carcinogenic (µg/L)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Acenaphthene	83-32-9	No	1200	963	-	-	-	-
Acenaphthylene	208-96-8	No	602	461	-	-	-	-
Acetone	67-64-1	No	18000	4.39 x 10^6	64400	-	-	-
Aldrin	309-00-2	No	0.602	-	-	0.00458	-	0.0115
Perchlorate and Perchlorate Salts	14797-73-0	No	14.0	3190	-	-	-	-
Anthracene	120-12-7	No	6020	2500	-	-	-	-
Antimony (metallic)	7440-36-0	No	8.02	273	-	-	-	-
Arsenic, Inorganic	7440-38-2	No	6.02	1370	-	0.319	97.3	-
Barium	7440-39-3	No	4010	63700	-	-	-	-
Benz[a]anthracene	56-55-3	Yes	-	-	-	2.51	-	0.338
Benzaldehyde	100-52-7	No	2010	49100	-	195	4390	-
Benzene	71-43-2	No	80.2	605	62.6	14.2	98.3	7.20
Benzo[a]pyrene	50-32-8	Yes	6.02	-	-	0.251	-	-
Benzo[b]fluoranthene	205-99-2	Yes	-	-	-	2.51	-	-
Benzo[g,h,i]perylene	191-24-2	No	602	-	-	-	-	-
Benzo[k]fluoranthene	207-08-9	Yes	-	-	-	25.1	-	-
Benzoic Acid	65-85-0	No	80200	1.20 x 10^6	-	-	-	-
Benzyl Alcohol	100-51-6	No	2010	88900	-	-	-	-
Beryllium and compounds	7440-41-7	No	40.1	63.7	-	-	-	-
Bis(2-chloroethyl)ether	111-44-4	No	-	-	-	0.708	27.1	0.170
Bis(2-ethylhexyl)phthalate	117-81-7	No	401	-	-	55.6	-	-
Bromobenzene	108-86-1	No	160	542	125	-	-	-
Bromodichloromethane	75-27-4	No	401	6460	-	12.6	186	1.52
Bromoform	75-25-2	No	401	6230	-	98.6	1410	51.0
Bromomethane	74-83-9	No	28.1	997	10.4	-	-	-
Butadiene, 1,3-	106-99-0	No	-	-	4.17	0.229	1.62	1.87
Butanol, N-	71-36-3	No	2010	100000	-	-	-	-
Butyl Benzyl Phthlate	85-68-7	No	4010	2870	-	410	270	-
Butylbenzene, n-	104-51-8	No	1000	-	-	-	-	-
Butylbenzene, sec-	135-98-8	No	2010	-	-	-	-	-
Butylbenzene, tert-	98-06-6	No	2010	1050	-	-	-	-
Cadmium (Diet)	7440-43-9	No	10.0	114	-	-	-	-

GROUNDWATER			Non-Carcinogenic (µg/L)			Carcinogenic (µg/L)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Carbon Disulfide	75-15-0	No	2010	20000	1460	-	-	-
Carbon Tetrachloride	56-23-5	No	80.2	340	209	11.1	43.3	9.36
Chlordane	12789-03-6	No	10.0	1.77	1.46	2.23	0.362	0.562
Chlordecone (Kepone)	143-50-0	No	6.02	5.43		0.0779	0.0647	
Chloroaniline, p-	106-47-8	No	80.2	1320	-	3.90	59.0	-
Chlorobenzene	108-90-7	No	401	1280	104			
Chloroform	67-66-3	No	201	2530	204	25.1	292	2.44
Chloromethane	74-87-3	No			188			
Chloronaphthalene, Beta-	91-58-7	No	1600	1400	-	-	-	-
Chlorophenol, 2-	95-57-8	No	100	1020	-			
Chromium(III), Insoluble Salts	16065-83-1	No	30100	88700	-	-	-	-
Chromium(VI)	18540-29-9	Yes	60.2	171		0.501	1.16	
Chrysene	218-01-9	Yes	-	-	-	251	-	-
Copper	7440-50-8	No	802	182000				
Cresol, m-	108-39-4	No	1000	12000	-	-	-	-
Cresol, o-	95-48-7	No	1000	12100	-		-	
Cresol, p-	106-44-5	No	2010	24600	-	-	-	-
Cumene	98-82-8	No	2010	1920	834			
Cyanide (CN-)	57-12-5	No	12.0	2730	1.67	-	-	-
Cyclohexane	110-82-7	No			12500			
DDD	72-54-8	No	0.602	0.0708	-	3.25	0.351	-
DDE, p,p'-	72-55-9	No	6.02			2.29		0.579
DDT	50-29-3	No	10.0	-	-	2.29	-	-
Dibenz[a,h]anthracene	53-70-3	Yes				0.251		
Dibenzofuran	132-64-9	No	20.1	12.9	-	-	-	-
Dibromochloromethane	124-48-1	No	401	6740		9.27	143	
Dibromoethane, 1,2-	106-93-4	No	180	3600	18.8	0.390	7.14	0.0936
Dibromomethane (Methylene Bromide)	74-95-3	No			8.34			
Dibutyl Phthalate	84-74-2	No	2010	1640	-	-	-	-
Dichlorobenzene, 1,2-	95-50-1	No	1800	2920	417			
Dichlorobenzene, 1,3-[5]	541-73-1	No	1800	2500	417	-	-	-
Dichlorobenzene, 1,4-	106-46-7	No	1400	2230	1670	144	211	5.10
Dichlorobenzidine, 3,3'-	91-94-1	No	-	-	-	1.73	4.53	-
Dichlorodifluoromethane	75-71-8	No	4010	38200	209			

GROUNDWATER			Non-Carcinogenic (µg/L)			Carcinogenic (µg/L)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Dichloroethane, 1,1-	75-34-3	No	4010	58400	-	137	1830	35.1
Dichloroethane, 1,2-	107-06-2	No	120	2820	14.6	8.56	184	2.16
Dichloroethylene, 1,1-	75-35-4	No	1000	8540	417	-	-	-
Dichloroethylene, 1,2-cis-	156-59-2	No	40.1	363	-	-	-	-
Dichloroethylene, 1,2-trans-	156-60-5	No	401	3630	-	-	-	-
Dichlorophenol, 2,4-	120-83-2	No	60.2	190	-	-	-	-
Dichlorophenoxy Acetic Acid, 2,4-	94-75-7	No	201	1350	-	-	-	-
Dichloropropane, 1,2-	78-87-5	No	802	9570	8.34	21.1	231	15.2
Dichloropropene, 1,3-	542-75-6	No	602	6560	41.7	7.79	78.2	14.0
Dieldrin	60-57-1	No	1.00	0.614	-	0.0487	0.0274	-
Diethyl Phthalate	84-66-2	No	16000	198000	-	-	-	-
Dimethylphenol, 2,4-	105-67-9	No	401	3110	-	-	-	-
Dimethylphthalate[5]	131-11-3	No	16000	581000	-	-	-	-
Dinitrobenzene, 1,2-	528-29-0	No	2.01	53.3	-	-	-	-
Dinitrobenzene, 1,3-	99-65-0	No	2.01	72.5	-	-	-	-
Dinitrobenzene, 1,4-	100-25-4	No	2.01	75.6	-	-	-	-
Dinitrophenol, 2,4-	51-28-5	No	40.1	1220	-	-	-	-
Dinitrotoluene, 2,4-	121-14-2	No	40.1	749	-	2.51	43.2	-
Dinitrotoluene, 2,6-	606-20-2	No	6.02	93.5	-	0.519	7.42	-
Dinitrotoluene, 2-Amino-4,6-	35572-78-2	No	40.1	1030	-	-	-	-
Dinitrotoluene, 4-Amino-2,6-	19406-51-0	No	40.1	1030	-	-	-	-
Dioxane, 1,4-	123-91-1	No	602	191000	62.6	7.79	2280	11.2
Diphenylamine	122-39-4	No	2010	3360	-	-	-	-
Endosulfan	115-29-7	No	120	631	-	-	-	-
Endrin	72-20-8	No	6.02	3.68	-	-	-	-
Ethyl Chloride	75-00-3	No	-	-	20900	-	-	-
Ethylbenzene	100-41-4	No	2010	3820	2090	70.8	124	22.5
Ethylene Glycol	107-21-1	No	40100	5.70×10^7	-	-	-	-
Fluoranthene	206-44-0	No	802	-	-	-	-	-
Fluorene	86-73-7	No	802	465	-	-	-	-
Formaldehyde	50-00-0	No	4010	318000	20.5	-	-	4.32
Heptachlor	76-44-8	No	10.0	1.47	-	0.173	0.0233	0.0432
Heptachlor Epoxide	1024-57-3	No	0.261	0.236	-	0.0856	0.0712	0.0216
Hexachlorobenzene	118-74-1	No	16.0	-	-	0.487	-	0.122
Hexachlorobutadiene	87-68-3	No	20.1	9.53	-	9.99	4.36	2.55

GROUNDWATER			Non-Carcinogenic (µg/L)			Carcinogenic (µg/L)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Hexachlorocyclohexane, Alpha-	319-84-6	No	160	247	-	0.124	0.175	-
Hexachlorocyclohexane, Beta-	319-85-7	No	-	-	-	0.433	0.613	-
Hexachlorocyclohexane, Gamma- (Lindane)	58-89-9	No	6.02	9.26	-	0.708	1.00	-
Hexachlorocyclopentadiene	77-47-4	No	120	41.6	0.417	-	-	-
Hexachloroethane	67-72-1	No	14.0	13.7	62.6	19.5	17.5	5.10
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	No	60.2	7960	-	7.08	861	-
Hexane, N-	110-54-3	No	-	-	1460	-	-	-
Hexanone, 2-	591-78-6	No	100	2760	62.6	-	-	-
Hydrazine[7]	302-01-2	No	-	-	0.0626	0.260	1120	0.0115
Indeno[1,2,3-cd]pyrene	193-39-5	Yes	-	-	-	2.51	-	-
Isophorone	78-59-1	No	4010	86500	-	820	16300	-
Isopropanol	67-63-0	No	40100	6.51 x 10^6	417	-	-	-
Manganese, Total	7439-96-5	No	481	4370	-	-	-	-
Mercuric Chloride	7487-94-7	No	6.02	95.6	-	-	-	-
Mercury (elemental)	7439-97-6	No	-	-	0.626	-	-	-
Methanol	67-56-1	No	40100	1.80 x 10^7	41700	-	-	-
Methoxychlor	72-43-5	No	100	58.7	-	-	-	-
Methyl Ethyl Ketone (2-Butanone)	78-93-3	No	12000	1.46 x 10^6	10400	-	-	-
Methyl Isobutyl Ketone (4-methyl-2-pentanone)	108-10-1	No	-	-	6260	-	-	-
Methyl Mercury	22967-92-6	No	2.01	455	-	-	-	-
Methyl tert-Butyl Ether (MTBE)	1634-04-4	No	-	-	6260	433	19900	216
Methylene Chloride	75-09-2	Yes	120	3660	1250	125	3470	2030
Methylnaphthalene, 1-	90-12-0	No	1400	1120	-	26.9	19.7	-
Methylnaphthalene, 2-	91-57-6	No	80.2	65.1	-	-	-	-
Naphthalene	91-20-3	No	401	701	6.26	-	-	1.65
Nickel Soluble Salts	7440-02-0	No	401	18200	-	-	-	-
Nitrobenzene	98-95-3	No	40.1	624	18.8	-	-	1.40
Nitroglycerin	55-63-0	No	2.01	86.8	-	45.8	1820	-
Nitroguanidine	556-88-7	No	2010	1.82 x 10^7	-	-	-	-
Nitrosodimethylamine, N-	62-75-9	Yes	0.160	73.8	0.0834	0.00491	2.00	0.00145
Nitroso-di-N-propylamine, N-	621-64-7	No	-	-	-	0.111	3.53	-
Nitrosodiphenylamine, N-	86-30-6	No	-	-	-	159	523	-

GROUNDWATER			Non-Carcinogenic (µg/L)			Carcinogenic (µg/L)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Nitrotoluene, m-	99-08-1	No	2.01	13.6	-	-	-	-
Nitrotoluene, o-	88-72-2	No	18.0	154	-	3.54	27.8	-
Nitrotoluene, p-	99-99-0	No	80.2	617	-	48.7	344	-
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	2691-41-0	No	1000	634000	-	-	-	-
Octyl Phthalate, di-N-	117-84-0	No	201	-	-	-	-	-
Pentachlorophenol	87-86-5	No	100	29.3	-	1.95	0.524	-
Pentaerythritol tetranitrate (PETN)	78-11-5	No	40.1	962	-	195	4300	-
Perfluorooctane Sulfonic acid (PFOS)[5]	1763-23-1	No	0.401	-	-	-	-	-
Perfluorooctanoic Acid (PFOA)	335-67-1	No	0.401	-	-	11.1	-	-
Phenanthrene	85-01-8	No	602	246	-	-	-	-
Phenol	108-95-2	No	6020	141000	-	-	-	-
Phosphorus, White	7723-14-0	No	0.401	91.0	-	-	-	-
Polychlorinated Biphenyls	1336-36-3	No	-	-	-	1.95	-	0.562
Propyl benzene	103-65-1	No	2010	1830	2090	-	-	-
Pyrene	129-00-0	No	602	151	-	-	-	-
Selenium	7782-49-2	No	100	22800	-	-	-	-
Silver	7440-22-4	No	100	1520	-	-	-	-
Strontium, Total	7440-24-6	No	12000	2730000	-	-	-	-
Styrene	100-42-5	No	4010	10300	2090	-	-	-
TCDD, 2,3,7,8-	1746-01-6	No	0.0000140	-	0.0000834	5.99×10^{-6}	-	1.48×10^{-5}
Tetrachloroethane, 1,1,1,2-	630-20-6	No	602	2390	-	30.0	109	7.59
Tetrachloroethane, 1,1,2,2-	79-34-5	No	401	3640	-	3.90	32.5	0.968
Tetrachloroethylene	127-18-4	No	120	230	83.4	371	653	216
Tetryl (Trinitrophenylmethylnitramine)	479-45-8	No	40.1	2470	-	-	-	-
Thallium (Soluble Salts)	7440-28-0	No	0.201	45.5	-	-	-	-
Toluene	108-88-3	No	1600	5300	10400	-	-	-
Toxaphene	8001-35-2	No	-	-	-	0.708	-	-
Trichloro-1,2,2-trifluoroethane, 1,1,2-	76-13-1	No	602000	1.91×10^{6}	10400	-	-	-
Trichlorobenzene, 1,2,3-	87-61-6	No	16.0	12.6	-	-	-	-
Trichlorobenzene, 1,2,4-	120-82-1	No	201	164	4.17	26.9	20.2	-
Trichloroethane, 1,1,1-	71-55-6	No	40100	251000	10400	-	-	-

GROUNDWATER			Non-Carcinogenic (µg/L)			Carcinogenic (µg/L)		
Hazardous Substance	CAS Number[1]	Mutagenic?	Ingestion[2]	Dermal[3]	Inhalation[4]	Ingestion[2]	Dermal[3]	Inhalation[4]
Trichloroethane, 1,1,2-	79-00-5	No	80.2	1250	0.417	13.7	196	3.51
Trichloroethylene	79-01-6	Yes	10.0	68.9	4.17	11.8	74.5	9.57
Trichlorofluoromethane	75-69-4	No	6020	36400	-	-	-	-
Trichlorophenol, 2,4,5-	95-95-4	No	2010	2890	-			
Trichlorophenol, 2,4,6-	88-06-2	No	20.1	30.2	-	70.8	98.1	-
Trichlorophenoxyacetic Acid, 2,4,5-	93-76-5	No	201	874				
Trichlorophenoxypropionic acid, - 2,4,5	93-72-1	No	160	362	-	-	-	-
Trichloropropane, 1,2,3-	96-18-4	Yes	80.2	767	0.626	0.00835	0.0728	
Trimethylbenzene, 1,2,4-	95-63-6	No	201	201	125	-	-	-
Trimethylbenzene, 1,3,5-	108-67-8	No	201	277	125			
Tri-n-butyltin	688-73-3	No	6.02	9.87	-	-	-	-
Trinitrobenzene, 1,3,5-	99-35-4	No	602	46700				
Trinitrotoluene, 2,4,6-	118-96-7	No	10.0	448	-	26.0	1070	-
Vanadium and Compounds	7440-62-2	No	101	596				
Vinyl Acetate	108-05-4	No	20100	1.36×10^6	417	-	-	-
Vinyl Chloride	75-01-4	Yes	60.2	893	209	0.214	2.77	3.35
Xylenes	1330-20-7	No	4010	7530	209	-	-	-
Zinc and Compounds	7440-66-6	No	6020	2.28×10^6				

[1] "CAS Number" means the Chemical Abstract Service (CAS) registry number uniquely assigned to chemicals by the American Chemical Society and recorded in the CAS Registry System

[2] "Ingestion" means a potential pathway of exposure to hazardous substances through direct consumption of the soil.

[3] "Dermal" means a potential pathway of exposure to hazardous substances through physical contact with the soil

[4] "Inhalation" means a potential pathway to volatile organic hazardous substances in the soil through volatilization.

[5] Perfluorooctane Sulfonic Acid includes both the acid and its salt.

APPENDIX C: HIERARCHY OF TOXICITY SOURCES AND MCLS

Hierarchy of Toxicity Sources and MCLs

Alaska Department of Environmental Conservation

Division of Spill Prevention and Response

Contaminated Sites Program

Tier I Source = IRIS- Integrated Risk Information System

IRIS is EPA's data base containing qualitative and quantitative information on the human health effects that may result from exposure to chemical substances in the environment. The toxicity values listed in IRIS are considered to be validated and have undergone rigorous peer review. The completion of IRIS assessments is a multi-step process:

1) EPA Develops and Completes a draft IRIS Toxicological Review (Duration 345 Days)
2) Internal EPA Review (Duration 60 days)
3) EPA Initiates Interagency Science Consultation on Draft IRIS Toxicological Review (Duration 45 days)
4) EPA Initiates Independent External Peer Review of Draft IRIS Toxicological Review, Public Review and Comment on Draft IRIS Toxicological Review, and Holds a Public Listening Session (Duration 105 days)
5) EPA Revises IRIS Toxicological Review and Develops IRIS Summary (Duration 60 days)
6) (A) Internal EPA Review of Final IRIS Toxicological Review and IRIS Summary (Duration 45 days)

   (B) EPA-led Interagency Science Discussion (Duration 45 days – concurrent with Step 6A.)
7) EPA Completion of IRIS Toxicological Review and IRIS Summary (Duration 30 days)

Tier II Source = PPRTV- Provisional Peer Reviewed Toxicity Values

The Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center develops PPRTVs on a chemical-specific basis when requested by the EPA's Superfund program for use in site specific risk assessments. However, the PPRTVs are developed in a shorter period of time and although these assessments undergo external peer review, their development does not include Agency and interagency review as is done with the IRIS assessments. Furthermore, their development typically includes a limited evaluation of information on mode of action, other toxicological end points, and other information that provides a better understanding of the toxicology of these chemicals. Often, the amount of relevant information on the toxicity of these chemicals is less because fewer studies have been conducted and reported. However, the PPRTVs are generally the best quantification of

the dose-response scientific data that is available at the time they are developed because the PPRTVs utilize current information and methodologies.

Tier III Source = Other Toxicity Values

Tier 3 includes additional EPA/non-EPA sources of toxicity information. Chemicals that have not been through a rigorous IRIS process or requested for PPRTV listing can contain toxicity recommend values from other sources. Priority should be given to sources of information that are most current, peer reviewed, transparent and publicly available. The quality of these values can vary widely and depends on the depth of the toxicity data base, the scientific quality and rigor of the underlying risk assessment and the scope of peer review. Some available values, such as Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Level (MRLs) and California Environmental Protection Agency (Cal EPA) criteria, have undergone an extensive literature review, a rigorous data analysis using current guidance and methods to derive a toxicity value, and have been thoroughly peer reviewed. It should be noted that ATSDR MRLs are limited to non-cancer effects only. At the other end of the spectrum, there may be chemicals with no values and little or no available toxicity information, or outdated studies which are no longer consistent with current methodologies and practices.

Maximum Contaminant Levels (MCLs) are standards that are set by the United States EPA for drinking water quality. An MCL is the legal threshold limit on the amount of a substance that is allowed in public water systems under the Safe Drinking Water Act. To set a MCL for a contaminant, EPA first determines how much of the contaminant may be present with no adverse health effects based on the information from hierarchy of toxicity listed above. This level is called the Maximum Contaminant Level Goal (MCLG). MCLGs are non-enforceable public health goals. The legally enforced MCL is then set as close as possible to the MCLG. The MCL for a contaminant may be higher than the MCLG because of difficulties in measuring small quantities of a contaminant, a lack of available treatment technologies, or if EPA determines that the costs of treatment would outweigh the public health benefits of a lower MCL. In the last case, EPA will set the MCL to balance the cost of treatment with the public health benefits.

The EPA guidance for establishing an MCL states that "MCLs are enforceable standards and are to be set as close to the maximum contaminant level goals (MCLGs) (Health Goals) as is feasible and are based upon treatment technologies, costs (affordability) and other feasibility factors, such as availability of analytical methods, treatment technology and costs for achieving various levels of removal." The process of determining an MCL only starts with an evaluation of the adverse effects caused by the chemical in question and the doses needed to cause such effects. Finally, only a very small percentage of environmental contaminants have an established MCL.

State of Alaska

DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF SPILL PREVENTION AND RESPONSE

CONTAMINATED SITES PROGRAM

Underground Storage Tanks Procedures Manual

GUIDANCE FOR TREATMENT OF
PETROLEUM-CONTAMINATED SOIL AND WATER
AND
STANDARD SAMPLING PROCEDURES

March 22, 2017

TABLE OF CONTENTS

CHAPTER 1

GUIDANCE FOR TREATMENT OF PETROLEUM-CONTAMINATED SOIL AND WATER AT UNDERGROUND STORAGE TANK SITES

CHAPTER 1. GUIDANCE FOR TREATMENT OF PETROLEUM-CONTAMINATED SOIL AND WATER AT UNDERGROUND STORAGE TANK SITES

For more information regarding remedial technologies that are available, refer to the document entitled *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites, A Guide for Corrective Action Plan Reviewers*, EPA 510-B-94-003, dated October 1994, published by the United States Environmental Protection Agency, and available from that agency. A copy is available for review at the Department of Environmental Conservation's offices in Anchorage, Fairbanks, Juneau, and Soldotna.

SECTION 1. GUIDANCE FOR THE TREATMENT OF PETROLEUM-CONTAMINATED SOIL AND WATER

1.1 Purpose, Applicability, and Exclusions

The following is intended as guidance for the treatment of petroleum-contaminated soil and groundwater associated with underground storage tanks (USTs) as defined by AS 46.03.450. It may be used as guidance for other petroleum releases from other tanks such as home heating oil tanks regulated under 18 AAC 75.

Petroleum-contaminated media and debris generated by releases or spills from USTs are temporarily excluded from the Toxicity Characteristic Leaching Procedures requirements of the Resource Conservation and Recovery Act (RCRA) (see 40 C.F.R. 261.4(b)(10)).

The corrective action activities of petroleum-contaminated soils are an important part of the corrective action process at leaking underground storage tank (LUST) sites. Contaminated soils that remain in place without treatment may pose not only an environmental and public health risk, but can significantly prolong the groundwater corrective action effort, resulting in significantly higher total corrective action costs.

1.2 Introduction

Various options for managing petroleum-contaminated sites, including guidance for use in Alaska, are highlighted in this chapter. The technology for managing petroleum-contaminated soil and water is continually improving. The large number of sites that need to be addressed has created a demand for innovative, cost-effective solutions. The Alaska Department of Environmental Conservation (ADEC) intends to maintain a flexible approach toward the evaluation and approval of new treatment technologies that are protective of human health and safety and the environment. Examples of proposed remedial technologies for petroleum-contaminated soils and water include bioremediation, landspreading, vapor extraction systems, solidification, fixation, asphalt recycling, thermal desorption, soil washing, groundwater pump and treat, and air sparging.

A health and safety plan addressing important chemical and physical hazards should be prepared and used. Any handling of gasoline-contaminated soils, in particular, will result in volatilization of light fractions of petroleum. Organic vapors should be monitored and workers must be in compliance with Occupational Safety and Health Administration requirements under 29 C.F.R.1910.120 for training and personal protective gear.

Regular checks should be made at the area to ensure that no further releases occur and that all equipment and containment systems are operating properly. In particular, checks should be made immediately before, during, and after high winds and heavy rainfall. One person should be assigned the responsibility for ensuring that these checks are made and for keeping a log of the maintenance. Many well-designed storage or treatment systems operate poorly due to poor maintenance. Operation and maintenance are as important to the effectiveness of the treatment as the design.

SECTION 2. TREATMENT TECHNOLOGIES

2.1 Bioremediation

Bioremediation is a treatment method that decreases petroleum product concentrations in soil and groundwater through biological action. Bioremediation may be performed in-situ, in a specially designed treatment cell, or by landfarming. Different requirements may apply, depending on whether landfarming, in-situ, or cell bioremediation is used. If in-situ bioremediation or landfarming is used, the treatment design will require more detailed attention regarding site conditions. Cell bioremediation requires more extensive construction, but fewer monitoring and testing requirements.

2.1.1 Landfarming

Landfarming involves spreading contaminated soil in a thin layer on a liner over the ground's surface. Biological activity may be enhanced by the addition of a combination of the following amendments: nutrients, mechanical aeration, water addition, and pH adjustment. Landfarming should not be confused with landspreading. Landspreading relies mainly on aeration and unenhanced biological action to perform treatment. The design parameters for a landspreading facility, however, are similar to the design parameters for a landfarming facility. Landfarming works well for gasoline and diesel and more slowly for heavier hydrocarbons.

2.1.2 In-Situ Bioremediation

In-situ bioremediation is most often accomplished in combination with vapor extraction and bioventing. This technology uses naturally occurring microorganisms that are stimulated to biodegrade contaminated soils in place. The most developed and most feasible bioremediation method for in-situ treatment relies on optimizing environmental conditions by providing an oxygen source that is delivered to the subsurface through an injection well or infiltration system for the enhancement of microbial activity.

2.1.3 Cell Bioremediation

Cell bioremediation employs specially designed treatment cells to contain contaminated soils and enhance biodegradation of hydrocarbons. Soil moisture, temperature, oxygen, and nutrients are controlled to optimize conditions for soil bacteria.

The major difference between in-situ bioremediation and cell bioremediation is how the contaminated soil is contained. In cell bioremediation, the contaminated soil is placed in a liner, tank, pad, or other structure designed to completely contain any leachate generated from the treatment process.

2.2 Landspreading

Landspreading is a passive treatment method that decreases petroleum product concentrations in soil through biological action and aeration. Landspreading operations may require a solid waste disposal permit under 18 AAC 60. In general, a permit is not required if the soil will be removed from the landspreading site after the landspreading activity is complete.

Landspreading works well with soils contaminated with gasoline and soils lightly contaminated with diesel or other heavier chain petroleum products.

2.3 Vapor Extraction Systems

Vapor extraction involves the forced withdrawal or injection of air into subsurface soils to promote the volatilization of hydrocarbons. Contaminants move from the soil into the air stream. As the air exits the soil, it is either discharged directly to the atmosphere or treated to remove the contaminants before discharge. Vapor extraction works best with highly volatile contaminants, such as gasoline, in a uniform soil horizon with low organic content. Vapor extraction can be performed in-situ or in a prepared cell.

2.3.1 In-Situ Vapor Extraction

In-situ vapor extraction involves installing vertical or horizontal piping in the area of soil contamination. An air blower is then used to draw vapors out from the subsurface. In-situ vapor extraction should be used for volatile contaminants only in areas where soil permeability allows easy vapor movement. Permeability will affect well spacing. The amount of soil organic matter and soil moisture will also affect the ease of stripping volatiles.

In-situ vapor extraction systems can be a series of wells, some type of French drain system buried in the contaminated area, or any other mechanical structure designed to push or pull air through the contaminated area.

Use of explosion proof equipment and automatic shutoff devices that will shut down the system is recommended if the atmosphere inside the treatment building exceeds 20 percent of the lower explosive limit (LEL).

2.3.2 Prepared Cell Vapor Extraction

This technology is similar to in-situ vapor extraction. Prepared cell vapor extraction involves excavating the contaminated soil and placing it in treatment cells. Perforated pipes are placed within the treatment cells. The treatment cells are entirely enclosed with a liner and air is forced through the perforated pipes with blowers. Treatment cell venting can be effective for most of the year and can be done during periods of wet weather.

Like in-situ vapor extraction, prepared cell vapor extraction should be used for volatile contaminants. The amount of soil organic matter and soil moisture will also affect the ease of stripping volatiles.

2.4 Solidification and Fixation

Solidification and fixation are processes whereby additives are mixed into contaminated soil to immobilize the contaminants in the soil. The petroleum hydrocarbons become chemically and/or physically bound into the resulting mixture, limiting the solubility or leach ability of a contaminant.

Solidification and fixation usually refers to the use of cementing agents that transform contaminated soil into freestanding, relatively impermeable blocks. It is important that the reuse of the treated material be for a beneficial purpose. If not, the treated material must be disposed of in accordance with 18 AAC 60. Examples of beneficial reuse include aggregate for concrete, road base course, building foundation fill, and parking lot base course. Beneficial reuse must occur in an area that is at least six feet above the seasonal high water table. Examples of *nonbeneficial* use include nonstructural fill, stockpiles, and wetlands fill.

2.5 Asphalt Recycling

Cold or hot mix asphalt recycling involves blending petroleum-contaminated soil with sand and gravel aggregate for the manufacture of asphaltic concrete or lower grade asphalt mixtures for road beds. Soil particle diameter and the amount of silt and clay in the contaminated soil are limiting factors for this option.

This technology is generally used only with soils contaminated by diesel, heating oils, and heavier chain petroleum hydrocarbon fuels. This treatment is *not* recommended for soils heavily contaminated with gasoline. Soils that exhibit free flowing product or the potential of free product are not acceptable for asphalt recycling.

The asphalt produced by the cold asphalt recycling method is generally only suitable as a base coat and is not considered a finished product.

2.6 Thermal Desorption

Thermal desorption employs both permanent and mobile units. This technology uses a rotary kiln heated to 300° to 700° F to volatilize hydrocarbons from contaminated soil. Some petroleum hydrocarbons will remain in the soil depending on soil temperature, moisture content, texture, time in the unit, contaminant type and contaminant concentration. The emissions are oxidized in an afterburner to prevent discharge of large quantities of unburned hydrocarbons into the atmosphere.

This method is effective for treating most types of petroleum contaminants, although higher temperatures are needed to remove heavy hydrocarbons from soil.

Silty soil creates significant operational problems for thermal treatment systems because of dust generation and baghouse limitations. Large debris often cannot be processed in the thermal desorption unit and may need to be segregated and addressed separately.

2.7 Soil Washing

Soil washing is a technique that removes petroleum hydrocarbons from the soil by actively leaching the contaminants from the soil into a leaching medium. The extracted contaminants can then be removed from the washing fluid by conventional treatment methods. Soil washing with surfactants or solvents can achieve acceptable residual petroleum hydrocarbon levels for soil. However, the washing process results in large amounts of wastewater that must be managed. It may be difficult to treat soils with a high percentage of silts and clays or organic matter and achieve corrective action goals.

2.8 Groundwater Pump and Treat

Groundwater pump and treat is used when groundwater beneath a site is contaminated with petroleum. Contamination may be in the form of free product floating on the water table or petroleum constituents dissolved in the water. Any free product should be removed as soon as possible.

For dissolved phase contamination, groundwater is extracted, treated, and disposed. Several types of treatment could be used depending on the type and concentration of the contaminant and the site conditions. Some of the possible treatment technologies include oil/water separators, air strippers, activated carbon, and bioremediation or some combination (such as using an air stripper and activated carbon for volatile organic compounds and an oil/water separator for heavier end compounds). Disposal options for extracted groundwater include discharging to surface water, groundwater (reinjection), a sewer system, and an industrial wastewater treatment facility. A permit may be required before discharge of any extracted water.

2.9 Air Sparging

Air sparging involves the injection of air into the subsurface below the groundwater surface to volatilize hydrocarbon or other constituents dissolved in the groundwater and adsorbed to the soil. The volatilized hydrocarbon constituents are then removed from the vadose zone with vapor extraction wells. In addition to volatilizing petroleum contaminants, air sparging increases groundwater dissolved oxygen levels which increases biological activity leading to in-situ destruction of contaminants.

This technology is optimized in homogenous soils with high permeability and should be used only for volatile contaminants. However, introducing oxygen enhances biodegradation of heavier chain compounds such as diesel.

It is essential that a detailed site characterization is completed and that it defines any preferential flow paths that might exist. Failure to properly characterize a site and design a treatment system could result in vapor migration to areas that can result in serious safety considerations (for example, basements or crawl spaces can collect vapors and present an explosion hazard). Special consideration should be given to areas without a significant vadose zone.

2.10 Monitored Natural Attenuation

Natural attenuation is the reduction in the concentration and mass of hazardous substances due to naturally occurring physical, chemical, and biological processes without human intervention. These processes include, but are not limited to, dispersion, diffusion, sorption, retardation, and degradation processes such as biodegradation. Other terms associated with natural attenuation in the literature include "intrinsic remediation", "intrinsic bioremediation", "passive bioremediation", "natural recovery", and "natural assimilation".

Under appropriate field conditions, benzene, toluene, ethyl benzene, and xylenes (BTEX) may degrade through microbial activity and ultimately produce non-toxic products such as carbon dioxide and water. Where microbial activity is sufficiently rapid, the dissolved BTEX contaminant plume may stabilize (*i.e.*, stop expanding), and contaminant concentrations may eventually decrease to levels below regulatory cleanup levels.

Following degradation of a dissolved BTEX plume, a residue consisting of heavier petroleum hydrocarbons of relatively low solubility and volatility will typically be left behind in the original source (spill) area. Although this residual contamination may have a lower potential for further migration, it still may pose a threat to human health, safety, and welfare or the environment either from direct contact with soils in the source area or by continuing to slowly leach contaminants to groundwater. For these reasons, monitored natural attenuation alone is generally not sufficient to clean up a petroleum release site.

Source control measures usually need to be implemented in conjunction with natural attenuation processes. Other controls such as institutional controls may also be necessary to ensure protection of human health, safety, and welfare and the environment.

Performance monitoring is a critical element for a natural attenuation strategy to evaluate cleanup effectiveness and to ensure protection of human health, safety, and welfare and the environment. The monitoring program developed for each site should specify the location,

frequency, and type of samples and measurements necessary to evaluate remedy performance and define the anticipated performance objectives of the remedy. Performance monitoring should continue as long as contamination remains above required cleanup levels.

Typically, monitoring is continued for a specified period (*e.g.*, one to three years) after cleanup levels have been achieved to ensure that concentration levels are stable and remain below cleanup levels. The mechanisms for maintaining the monitoring program should be clearly established in the cleanup decision or other site documents, as appropriate. Details of the monitoring program should be provided to ADEC as part of any proposed natural attenuation remedy. For more information, consult the EPA guidance entitled *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tanks Sites* (EPA, 1997b).

SECTION 3. TREATMENT CHECKLISTS

The following checklists provide the essential components needed to complete a treatment project using the specified treatment technology. Additional criteria may be required dependent upon site-specific conditions. If used, a signed copy of the checklist should be enclosed in the front of the final corrective action report submitted to ADEC. Checklists are for voluntary use and are not mandatory.

Landfarming Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report ____

____ Workplan with detailed specifications for the landfarming project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for any discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of any nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Project maintains appropriate separation distance from surface water, water supply wells, and groundwater (18 AAC 78.274(a)(2)).

____ If applicable, description of cultured microbes, any additives, breakdown products, and oxygen source with their rate of application and biodegradation (18 AAC 78.250(e)(12)(E)).

____ If a landfarm is constructed off-site, department approval before moving contaminated soil to the treatment site (18 AAC 78.274(b)).

____ If landfarm is constructed off-site, compliance with the treatment facility requirements (18 AAC 78.273).

____ Information submitted that addresses leachate (18 AAC 78.250(e)(12)(A)).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

____ Treated soils returned to original site or disposed of properly in accordance with department approval (18 AAC 78.274(b)).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____ Signature_____

Title_____ Date_____

In-Situ Bioremediation Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report___

____ Workplan with detailed specifications for the in-situ bioremediation project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for any discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Site monitoring plan showing placement locations for monitoring wells (18 AAC 78.250(e)(13)(A)).

____ Hydrogeologic description of the site addressing soil and sediments present, stratigraphy, groundwater gradient, confining layers, perched water, aquifer transmissivity, percolation rates from precipitation, and other relevant factors (18 AAC 78.250(e)(13)(B)).

____ If required by ADEC, hydrogeologic modeling addressing capture zones, effects of hydraulic loading, and plume migration (18 AAC 78.250(e)(13)(C)).

____ If applicable, description of cultured microbes, any additives, and electron acceptor source with their rate of application and biodegradation (18 AAC 78.250(e)(12)(E)).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____ Signature_____

Title_____ Date_____

Cell Bioremediation Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report ____

____ Workplan with detailed specifications for the cell bioremediation project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for any discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Soil placed on liner meeting long-term storage requirements (18 AAC 78.274).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Information submitted that addresses containment and handling of leachate (18 AAC 78.250(e)(12)(A)).

____ Project maintains appropriate separation distance from surface water, water supply wells, and groundwater (18 AAC 78.274(a)(2)).

____ If applicable, description of cultured microbes, any additives, and oxygen source with their rate of application and biodegradation (18 AAC 78.250(e)(12)(E)).

____ If treatment cell is constructed off-site, department approval before moving contaminated soil to the treatment site (18 AAC 78.274(b)).

____ If treatment cell is constructed off-site, compliance with the treatment facility requirements (18 AAC 78.273).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

____ Treated soils returned to original site or disposed of properly in accordance with department approval (18 AAC 78.274(b)).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____ Signature_____

Title_____ Date_____

Landspreading Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report ____

____ Workplan with detailed specifications for the landspreading project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ A list of additives and additive effects (18 AAC 78.250(e)(7)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for any discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Information submitted that addresses leachate (18 AAC 78.250(e)(12)(A)).

____ Project maintains appropriate separation distance from surface water, water supply wells, and groundwater (18 AAC 78.274(a)(2)).

____ If landspreading is constructed off-site, department approval before moving contaminated soil to the treatment site (18 AAC 78.274(b)).

____ If landspreading is constructed off-site, compliance with the treatment facility requirements (18 AAC 78.273).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

____ Treated soils returned to original site or disposed of properly in accordance with department approval (18 AAC 78.274(b)).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____ Signature_____

Title_____ Date_____

In-Situ Vapor Extraction Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report ___

____ Workplan with detailed specifications for the in-situ vapor extraction project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 7 78.250(e)(1)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for any discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Site monitoring plan showing placement locations for monitoring wells (18 AAC 78.250(e)(13)(A)).

____ Hydrogeologic description of the site addressing soil and sediments present, stratigraphy, groundwater gradient, confining layers, perched water, aquifer transmissivity, percolation rates from precipitation, and other relevant factors (18 AAC 78.250(e)(13)(B)).

____ If required by ADEC, hydrogeologic modeling addressing capture zones, effects of hydraulic loading, and plume migration (18 AAC 78.250(e)(13)(C)).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____

Signature_____

Title_____ Date_____

Prepared Cell Vapor Extraction Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report _____

____ Workplan with detailed specifications for the cell vapor extraction project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ A list of additives and additive effects (18 AAC 78.250(e)(7)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for any discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Soil placed on liner meeting long-term storage requirements (18 AAC 78.274).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Information submitted that addresses containment and handling of leachate (18 AAC 78.250(e)(12)(A)).

____ Project maintains appropriate separation distance from surface water, water supply wells, and groundwater (18 AAC 78.274(a)(2)).

____ If treatment cell is constructed off-site, department approval before moving contaminated soil to the treatment site (18 AAC 78.274(b)).

____ If treatment cell is constructed off-site, compliance with the treatment facility requirements (18 AAC 78.273).

____ Post-treatment sampling to ensure cleanup levels have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

____ Treated soils returned to original site or disposed of properly in accordance with department approval (18 AAC 78.274(b)).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____ Signature_____

Title_____ Date_____

Solidification and Fixation Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report ___

____ Workplan with detailed specifications for the solidification or fixation project (18 AAC 78.250(e)(9)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ A list of additives and additive effects (18 AAC 78.250(e)(7)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Soil placed on liner meeting long-term storage requirements (18 AAC 78.274).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Information submitted that addresses containment and handling of leachate (18 AAC 78.250(e)(12)(A)).

____ Project maintains appropriate separation distance from surface water, water supply wells, and groundwater (18 AAC 78.274(a)(2)).

____ If solidification or fixation project is off-site, department approval before moving contaminated soil to the treatment site (18 AAC 78.274(b)).

____ If solidification or fixation is off-site, compliance with the treatment facility requirements (18 AAC 78.273).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625)

____ Treated soils returned to original site or disposed of properly in accordance with department approval (18 AAC 78.274(b)).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____ Signature_____

Title_____ Date_____

Asphalt Recycling Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report _____

____ Workplan with detailed specifications for the asphalt recycling project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1))

____ A list of additives and additive effects (18 AAC 78.250(e)(7)).
____ Site control plan (18 AAC 78.250(e)(8)).
____ Wastewater discharge permit for discharge of regulated wastewater (18 AAC 72).
____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Soil placed temporarily on liner meets appropriate storage requirements (18 AAC 78.274).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Information submitted that addresses leachate (18 AAC 78.250(e)(12)(A)).

____ Project maintains appropriate separation distance from surface water, water supply wells, and groundwater (18 AAC 78.274(a)(2)).

____ If using a hot asphalt batch plant, certify that processes incorporating contaminated soils meet all current industry standards for asphalt paving (18 AAC 78.250(e)(12)(C)).

____ If required by ADEC, results of a leaching assessment (18 AAC 78.250(e)(12)(D)(iii)).

____ If required by ADEC, a pavement structure design study certified by a registered engineer (18 AAC 78.250(e)(12)(D)(i)).

____ If asphalt recycling is completed off-site, department approval before moving contaminated soil to the treatment site (18 AAC 78.274(b)).

____ If asphalt recycling is completed off-site, compliance with the treatment facility requirements (18 AAC 78.273).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

____ Treated soils returned to original site or disposed of properly in accordance with department approval (18 AAC 78.274(b)).

I certify I personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____ Signature_____

Title_____ Date_____

Thermal Desorption Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in report ____

____ Workplan with detailed specifications for the thermal desorption project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ A list of additives and additive effects (18 AAC 78.250(e)(7)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Contaminated soil placed on liner meets appropriate storage requirements until final confirmation samples confirm they meet appropriate cleanup standards (18 AAC 78.274).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Information submitted that addresses containment and handling of leachate (18 AAC 78.250(e)(12)(A)).

____ Project maintains appropriate separation distance from surface water, water supply wells, and groundwater (18 AAC 78.274).____If thermal desorption is completed off-site, department approval before moving contaminated soil to the treatment site (18 AAC 78.274(c)).

____ If thermal desorption is completed off-site, compliance with the treatment facility requirements (18 AAC 78.273).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

____ Treated soils returned to original site or disposed of properly in accordance with department approval (18 AAC 78.274(b)).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____ Signature_____

Title_____ Date_____

Soil Washing Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report _____

____ Workplan with detailed specifications for the soil washing project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ A list of additives and additive effects (18 AAC 78.250(e)(7)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Soil placed temporarily on liner meets appropriate storage requirements (18 AAC 78.274).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Information submitted that addresses containment and handling of leachate (18 AAC 78.250(e)(12)(A)).

____ Project maintains appropriate separation distance from surface water, water supply wells, and groundwater (18 AAC 78.274(a)(2)).

____ If soil washing is completed off-site, department approval before moving contaminated soil to the treatment site (18 AAC 78.274(b)).

____ If soil washing is completed off-site, compliance with the treatment facility requirements (18 AAC 78. 273).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

____ Treated soils returned to original site or disposed of properly in accordance with department approval (18 AAC 78.274(b)).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____ Signature_____

Title_____ Date_____

Groundwater Pump and Treat Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report ___

____ Workplan with detailed specifications for the groundwater pump and treat project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ A list of additives and additive effects (18 AAC 78.250(e)(7)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.250(e)(11) and 18 AAC 72).

____ Site monitoring plan showing placement locations for monitoring wells (18 AAC 78.250(e)(13)(A)).

____ Hydrogeologic description of the site addressing soil and sediments present, stratigraphy, groundwater gradient, confining layers, perched water, aquifer transmissivity, percolation rates from precipitation, and other relevant factors (18 AAC 78.250(e)(13)(B)).

____ If required by ADEC, hydrogeologic modeling addressing capture zones, effects of hydraulic loading, and plume migration (18 AAC 78.250(e)(13)(C)).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____Title_____

Signature_____ Date_____

Air Sparging Checklist

Project Name_____ **UST Facility #0-00**_____
Page Number in Report ____

____ Workplan with detailed specifications for the air sparging project (18 AAC 78.250(e)(3)).

____ Design plan that will provide prevention of contamination migration to previously unaffected areas unless otherwise approved by the department in a corrective action plan (18 AAC 78.250(e)(4)).

____ Workplan schedule for conducting field work, monitoring, corrective action performance, and submittal of interim and final corrective action reports (18 AAC 78.250(e)(1)).

____ A list of additives and additive effects (18 AAC 78.250(e)(7)).

____ Site control plan (18 AAC 78.250(e)(8)).

____ Wastewater discharge permit for discharge of regulated wastewater (18 AAC 72).

____ Project complies with air quality standards and requirements (18 AAC 78.250(e)(9) and 18 AAC 50).

____ Nondomestic wastewater system plan approval for the construction, alteration, installation, modification, or operation of a nondomestic wastewater treatment works or disposal system under 18 AAC 72.600 (18 AAC 78.272(a)(9) and 18 AAC 72).

____ Site monitoring plan showing placement locations for monitoring wells (18 AAC 78.250(e)(13)(A)).

____ Hydrogeologic description of the site addressing soil and sediments present, stratigraphy, groundwater gradient, confining layers, perched water, aquifer transmissivity, percolation rates from precipitation, and other relevant factors (18 AAC 78.250(e)(13)(B)).

____ If required by ADEC, hydrogeologic modeling addressing capture zones, effects of hydraulic loading, and plume migration (18 AAC 78.250(e)(13)(C)).

____ Post-treatment sampling to ensure cleanup standards have been met (18 AAC 78.605(b)).

____ Cleanup standards achieved (18 AAC 78.600 - 18 AAC 78.625).

I certify that I have personally reviewed the above checklist and that all information noted is contained in the attached report.

Name_____Title_____

Signature_____ Date_____

CHAPTER 2

STANDARD SAMPLING PROCEDURES

CHAPTER 2. STANDARD SAMPLING PROCEDURES

SECTION 1. PROGRAM DESCRIPTION

1.1 Program Objectives

This manual outlines the standard operating procedures, quality control procedures, and data quality objectives for regulated underground storage tank (UST) site characterizations, site assessments, release investigations, and corrective actions. It directs the collection, interpretation, and reporting of data. This data will enable tank owners and operators and ADEC to evaluate the presence, degree, and extent of any groundwater, surface water, and soil contamination and to determine if further action is necessary.

1.2 Program Approach

To meet program objectives, this manual outlines a systematic approach to conducting UST site assessments and investigations. This approach is based on scientific studies, United States Environmental Protection Agency (EPA) guidance and methods, Alaska's UST regulations in 18 AAC 78, guidelines, input from the Alaska UST regulations workgroup, and assessment strategies used in Alaska and other states. This manual details sampling, laboratory analysis, and data reporting procedures, along with all required quality control functions. It also lists persons responsible for the major tasks required by 18 AAC 78. The manual covers activities in the following areas:

- personnel and responsibilities
- data quality objectives
- sampling procedures
- sample transfer log
- laboratory analytical procedures
- equipment maintenance and calibration
- data reduction, validation, and reporting
- quality control checks
- precision, accuracy, and completeness assessment
- corrective action scenarios
- internal audits
- reporting to management

Information about site sampling locations and site history, with reference to any existing documents for historical information and data available, must be included in the site-specific project plan or report submitted for each project undertaken for which a plan is required.

SECTION 2. PROGRAM ORGANIZATION AND RESPONSIBILITIES

2.1 Personnel and Responsibilities

All activities under this chapter, including the collection, interpretation, and reporting of data, shall be conducted or supervised by a qualified environmental professional as defined in 18 AAC 78. When a qualified environmental professional is not available, a qualified sampler as defined in 18 AAC 78 may conduct sampling of soil stockpiles, bioremediation systems, surface water, or groundwater monitoring wells if described and approved in the sampling and analysis plan. A qualified environmental professional is responsible for performing principal investigation and quality assurance officer tasks. The responsibilities for these tasks under this chapter are as follows:

(1) The qualified environmental professional is responsible for overall management of the UST site assessment and site investigation, including adherence to the procedures outlined in this chapter.

(2) The QA officer, which may also be the qualified environmental professional, is responsible for overall quality assurance of assessment and investigation of UST sites and facilities. The QA officer is responsible for conducting scheduled field audits and providing ongoing review, monitoring, and evaluation of the field and laboratory activities. The QA officer shall validate or supervise validation of all reports to ADEC.

2.2 Accountability

While a laboratory must assure satisfactory levels of quality control within the laboratory to maintain its status with ADEC, the owner or operator shall ensure that the qualified environmental professional

(1) verifies the status of the laboratory being used; a list of certified and provisionally approved laboratories is available from ADEC;

(2) ensures that analytical testing meets the objectives of this chapter that refer to laboratories and the applicable requirements of 18 AAC 78;

(3) reports in any project report connected with this chapter any deviation from standard laboratory procedures of which it becomes aware;

(4) takes appropriate corrective actions as outlined in Section 10 of this manual if questions or problems arise with the laboratory analysis.

SECTION 3. QUALITY ASSURANCE

3.1 Responsibility and Definitions

Quality assurance (QA) objectives are quantitative and qualitative criteria needed to support specific regulatory action and describe the acceptability of data. The qualified environmental professional has primary responsibility for field QA and is accountable for the overall QA of the samples.

Quantitative QA criteria are precision, accuracy, and completeness. Qualitative QA criteria are representativeness and comparability. QA is determined on a site-specific basis for each project based on the following:

(1) **Precision**: Precision is a measure of the variability or random error in sampling, sample handling, preservation, and laboratory analysis.

(2) **Accuracy**: Accuracy is a measure of the closeness of an individual measurement or an average of a number of measurements to the true value.

(3) **Completeness**: Completeness is a measure of the amount of valid data obtained compared to the amount expected. For purposes of this chapter, completeness is calculated as the amount of usable samples divided by the minimum number of required samples, expressed as a percentage. A minimum confidence level of 85 percent is required. The formula to be used follows:

$$\%C = (V/N) \times 100$$

Where %C = Completeness

V = Number of valid samples, as determined by above calculations and by procedures outlined Section 8.3.3 of this manual (Determining the final validity of samples)

N = Total number of measurements necessary to achieve a specified statistical level of confidence in decision making.

(4) **Representativeness**: Representativeness describes the degree to which data characterize the actual conditions at a site.

(5) **Comparability**: Comparability expresses the confidence with which one data set can be compared with another. Data must be reported in the same units of quantitation and in accordance with the reporting requirements of 18 AAC 78. Sampling and laboratory reports and procedures might be audited to assure that they follow standard procedures and reporting formats.

SECTION 4. SAMPLING PROCEDURES

4.1 Overview of Sampling Approach

The systematic sampling approach outlined below must be used to assure that data collection activities provide usable data.

(1) Sampling must begin with an evaluation of background information, historical data, and site conditions. This evaluation is used to prepare a site-specific sampling strategy.

(2) In combination with the requirements of 18 AAC 78 and the results of the pre-sampling investigation, field screening results must be used to determine where samples will be collected. Field screening results may also be used to segregate soils, based on apparent levels of contamination, to help monitor potential exposures, and for health and safety monitoring. However, field screening may not take the place of laboratory samples required as discussed in Section 4.5 of this chapter (Determining sample locations).

(3) Samples must be collected with appropriate, clean tools. Decontamination of sampling equipment must follow the practices described in this section.

(4) Stockpiles must be sampled in accordance with Section 4.5.1 of this chapter (Sample locations for contaminated untreated stockpiles).

(5) If necessary, sufficient monitoring and observation wells must be properly installed to determine the presence, degree, or extent of groundwater contamination. Sampling of groundwater must follow the standard procedures outlined in Section 4.7.2 of this chapter (Sampling groundwater monitoring wells).

(6) Samples must be collected and preserved in appropriate sample containers, as listed in Table 1.

Table 1: Reference Guide to Sample Collection and Laboratory Analysis
Part A: Soils, Sediments, Sludges, and Fill Materials

Parameter	Preparation/ Analytical Method[1]	Method Detection Limit[2]	Practical Quantitation Limit[3]	Container Description (Minimum) [Clear glass may be substituted for amber if samples are protected from exposure to light, this exception does not apply to metals]	Preservation/ Holding Time
Gasoline range organics	AK101*	2 mg/kg	20 mg/kg	4 oz. amber glass, TLS	Methanol preservative, Cool 4° ± 2°C / 28 days
Diesel range organics	AK102*	2 mg/kg	20 mg/kg	4 oz. amber glass, TLC	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Residual range organics	AK103*	10 mg/kg	100 mg/kg	4 oz. amber glass, TLC	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Aliphatic gasoline range organics	AK101AA*	2 mg/kg	20 mg/kg	4 oz. wide-mouth amber glass jar with Teflon lined silicon rubber septum seal	Methanol preservative / 28 days from sampling
Aromatic gasoline range organics	AK101AA*	2 mg/kg	20 mg/kg	4 oz. wide-mouth amber glass jar with Teflon lined silicon rubber septum seal	Methanol preservative / 28 days from sampling
Aliphatic diesel range organics	AK102AA*	2 mg/kg	20 mg/kg	4 oz. wide-mouth amber glass jar, TLC	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Aromatic diesel range organics	AK102AA*	2 mg/kg	20 mg/kg	4 oz. wide-mouth amber glass jar, TLC	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Aliphatic residual range organics	AK103AA*	10 mg/kg	100 mg/kg	4 oz. wide-mouth amber glass jar, TLC	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Aromatic residual range organics	AK103AA*	10 mg/kg	100 mg/kg	4 oz. wide-mouth amber glass jar, TLC	Cool 4° ± 2°C / 14 days to extraction of sample, less than 40 days to analysis of extract
Benzene	AK101**, 8021B or 8260B	0.007 mg/kg	0.05 mg/kg	4 oz. amber glass, TLS	Methanol preservative, Cool 4° ± 2°C / 28 days
Toluene	AK101**, 8021B or 8260B	0.007 mg/kg	0.05 mg/kg	4 oz. amber glass, TLS	Methanol preservative, Cool 4° ± 2°C / 28 days
Ethylbenzene	AK101**, 8021B or 8260B	0.007 mg/kg	0.05 mg/kg	4 oz. amber glass, TLS	Methanol preservative, Cool 4° ± 2°C / 28 days
Total xylenes	AK101**, 8021B or 8260B	0.007 mg/kg	0.05 mg/kg	4 oz. amber glass, TLS	Methanol preservative, Cool 4° ± 2°C / 28 days
Total BTEX	AK101**, 8021B or 8260B	0.007 mg/kg	0.05 mg/kg	4 oz. amber glass, TLS	Methanol preservative, Cool 4° ± 2°C / 28 days
Polynuclear Aromatic Hydrocarbons (PAH)[4]	8270C or 8310	0.1 mg/kg	1 mg/kg	4 oz. amber glass, TLS	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Total Volatile Chlorinated Solvents[6]	8260B or 8021B	0.008 mg/kg	0.08 mg/kg	4 oz. amber glass, TLS	Methanol preservative, Cool 4° ± 2°C / 28 days
Polychlorinated biphenyls (PCBs)	8082	0.01 mg/kg	0.05 mg/kg	4 oz amber glass, TLC	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Total Arsenic	6010B, 6020, 7060A, or 7061A	0.3 mg/kg	3 mg/kg	100mL Widemouth HDPE jar[5], TLC	6 months
Total Barium	6010B, 6020, 7080A, or 7081	20 mg/kg	200 mg/kg	100mL Widemouth HDPE jar[5], TLC	6 months
Total Cadmium	6010B, 6020,	0.8 mg/kg	8.0 mg/kg	100mL Widemouth HDPE jar[5], TLC	6 months

Table 1: Reference Guide to Sample Collection and Laboratory Analysis Part A: Soils, Sediments, Sludges, and Fill Materials					
Parameter	**Preparation/ Analytical Method[1]**	**Method Detection Limit[2]**	**Practical Quantitation Limit[3]**	**Container Description (Minimum) [Clear glass may be substituted for amber if samples are protected from exposure to light, this exception does not apply to metals]**	**Preservation/ Holding Time**
	7130, or 7131A				
Total Chromium	6010B, 6020, 7190, or 7191	2 mg/kg	20 mg/kg	100mL Widemouth HDPE jar[5], TLC	6 months
Total Lead	6010B, 6020, 7420, 7421	2 mg/kg	20 mg/kg	100mL Widemouth HDPE jar[5], TLC	6 months
Total Nickel	6010B, 6020, 7520, or 7521	2 mg/kg	20 mg/kg	100mL Widemouth HDPE jar[5], TLC	6 months
Total Vanadium	6010B, 7911, 6020, or 7910	20 mg/kg	200 mg/kg	100mL Widemouth HDPE jar[5], TLC	6 months

Legend to follow Part B

Notes to Table 1, Part A:

[1] Unless otherwise noted, all preparation and analytical methods refer to those contained in EPA's *Test Methods for the Evaluating Solid Waste, Physical/Chemical Methods*.

[2] Method detection limits (MDL), specified in 40 C.F.R. Part 136, Appendix B, revised as of July 1, 1996, adopted by reference, are determined at the participating department-approved laboratories.

[3] Practical quantitation limits (PQL), like method detection limits, are instrument specific. PQLs must be established by each laboratory and must equal or have a value lower than the PQL in the table. For purposes of this chapter, PQL = 10 x MDL, except for PCB which is PQL = 5x MDL.

[4] Naphthalene can be analyzed by AK101.

[5] HDPE, High Density Polyethylene sample collection bottles, critically cleaned for trace metals analysis.

[6] May be analyzed out of AK101 methanol preserved sample, if not used, then sample must be preserved with methanol in the field.

* ADEC Analytical Methods AK101, AK102, and AK103 are included in Appendix C. ADEC Analytical Methods AK101AA, AK102AA, and AK103AA are included in Appendix D.

** The AK101 method can be extended for specific determination of volatile aromatics (BTEX) as specified in EPA Method 8021B for solids utilizing methanol preservation option only. All AK101 samples must be preserved with methanol.

Table 1: Reference Guide to Sample Collection and Laboratory Analysis (cont.)
Part B: Ground, Surface, Waste, and Marine Waters[4]

Parameter	Preparation/ Analytical Method[1]	Method Detection Limit[2]	Practical Quantitation Limit[3]	Container Description	Preservation/ Holding Time
Gasoline range organics	AK101*	10 µg/L	100 µg/L	40 mL VOA, TLS	HCL to pH less than 2, 4° ± 2°C /14 days from sampling
Diesel range organics	AK102*	80 µg/L	800 µg/L	1 L amber glass, TLC	HCL to pH less than 2, 4° ± 2°C /14 days to extraction, 40 days to analysis of extract
Residual range organics	AK103*	50 µg/L	500 µg/L	1 L amber glass, TLC	Acidify to a pH of 2 using HCL, H_2SO_4 or HNO_3 / 7 days to extraction, 40 days to analysis of extract
Aliphatic gasoline range organics	AK101AA**	2 µg/L	20 µg/L	40 ml VOA with Teflon lined silicon rubber septum seal	HCL to a pH of 2 / 14 days from sampling
Aromatic gasoline range organics	AK101AA**	0.2 µg/L	2 µg/L	40 ml VOA with Teflon lined silicon rubber septum seal	HCL to a pH of 2 / 14 days from sampling
Aliphatic diesel range organics	AK102AA**	20 µg/L	200 µg/L	1 L amber glass, TLC	Acidify to a pH of 2 using HCL, H_2SO_4 or HNO_3 / 7 days to extraction, 40 days to analysis of extract
Aromatic diesel range organics	AK102AA**	20 µg/L	200 µg/L	1 L amber glass, TLC	Acidify to a pH of 2 using HCL, H_2SO_4 or HNO_3 / 7 days to extraction, 40 days to analysis of extract
Aliphatic residual range organics	--	--	--	--	--
Aromatic residual range organics	AK103AA**	50 µg/L	500µg/L	1 L amber glass, TLC	Acidify to a pH of 2 using HCL, H_2SO_4 or HNO_3 / 7 days to extraction, 40 days to analysis of extract
Benzene	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4° ± 2°C /14 days
Toluene	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4° ± 2°C /14 days
Ethylbenzene	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4° ± 2°C /14 days
Total xylenes	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4° ± 2°C /14 days
Total BTEX	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4° ± 2°C /14 days
Polynuclear Aromatic Hydrocarbons (PAH)[6]	8270C or 8310	1 µg/L	10 µg/L	1 L amber glass, TLS	4° ± 2°C, Ascorbic acid, dark / 7 days to extraction, 40 days to analysis of extract
Total Volatile Chlorinated Solvents	8021B or 8260B	0.8 µg/L	8 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4° ± 2°C $Na_2S_2O_3$/ 14 days
Polychlorinated biphenyls (PCBs)	8081A or 8082	1 µg/L	5 µg/L	1 L amber glass, TLC	4° ± 2°C / 7 days to extraction / 40 days to analysis of extract
Total Arsenic [7]	6010B, 6020, 7060, or 7061	8 µg/L	80 µg/L	min. 100 mL HDPE[5]	HNO_3 to pH less than 2 / 6 months max. total holding time
Total Barium	6010B, 6020, 7080A, or 7081	10 µg/L	100 µg/L	min. 100 mL HDPE[5]	HNO_3 to pH less than 2 / 6 months max. total holding time
Total Cadmium [7]	6010B, 6020, 7130, or 7131A	0.6 µg/L	6 µg/L	min. 100 mL HDPE[5]	HNO_3 to pH less than 2 / 6 months max. total holding time
Total Chromium [7]	6010B, 6020, 7190, or 7191	10 µg/L	100 µg/L	min. 100 mL HDPE[5]	HNO_3 to pH less than 2 / 6 months max. total holding time
Total Lead [7]	6010B, 6020, 7420, or 7421	2.0 µg/L	20 µg/L	min. 100 mL HDPE[5]	HNO_3 to pH less than 2 / 6 months max. total holding time

Table 1: Reference Guide to Sample Collection and Laboratory Analysis (cont.)
Part B: Ground, Surface, Waste, and Marine Waters[4]

Parameter	Preparation/ Analytical Method[1]	Method Detection Limit[2]	Practical Quantitation Limit[3]	Container Description	Preservation/ Holding Time
Total Nickel	6010B, 6020, 7520, or 7521	10 µg/L	100 µg/L	min. 100 mL HDPE[5]	HNO_3 to pH less than 2 / 6 months max. total holding time
Total Vanadium	6010B, 6020, 7910, or 7911	20 µg/L	200 µg/L	min. 100 mL HDPE[5]	HNO_3 to pH less than 2 / 6 months max. total holding time

Notes to Table 1, Part B:

[1] Unless otherwise noted, all preparation and analytical methods refer to those contained in EPA's *Test Methods for the Evaluating Solid Waste, Physical/Chemical Methods*, SW-846.

[2] Method detection limits (MDL), specified in 40 C.F.R. Part 136, Appendix B, revised as of July 1, 1996, adopted by reference, are determined at the participating department-approved laboratories.

[3] Practical quantitation limits (PQL), like method detection limits, are instrument specific. PQLs must be established by each laboratory and must equal or have a value lower than the PQL in the table. For purposes of this chapter, PQL = 10 x MDL, except for PCBs which is PQL = 5 x MDL.

[4] Sample collection and laboratory analyses for water collected from drinking water sources must be done in accordance with 18 AAC 80.

[5] HDPE, High Density Polyethylene sample collection bottles, critically cleaned for trace metals analysis.

[6] Naphthalene can be analyzed by 8021B or 8260B.

* ADEC Analytical Methods AK101, AK102, and AK103 are included in Appendix C. ADEC Analytical Methods AK101AA, AK102AA, and AK103AA are included in Appendix D.

† Analytical methods 6010B, 7080A, 7130, 7420, 7520, and 7910 are for high contaminant level screening only. These can be used for closure only if site specific MDL criteria are met. Analytical methods 6020, 7031A, 7060, 7061, 7081A. 7190, 7191, 7421, 7521, and 7911 are acceptable for closure.

Legend to Table 1:

PAH = acenaphthene, anthracene, benzo-a-anthracene, benzo-a-pyrene, benzo-b-fluoranthene, benzo-k-fluoranthene, chrysene, dibenzo-a,h-anthracene, fluorene ideno-123-cd-pyrene, naphthalene, and pyrene
VOA = Volatile Organic Analysis;
TLC = Teflon lined screw caps;
TLS = Teflon lined septa sonically bonded to screw caps

4.2 Documentation of Sampling Procedures

A field log book or another type of field record must be used to document the collection of samples and site data. This record must include:

(1) the name of each qualified environmental professional on site supervising or conducting a characterization, assessment, or investigation;

(2) the date and time of sampling;

(3) weather conditions, including temperature, wind speed, humidity, and precipitation;

(4) the name of each person who physically collected the samples;

(5) clear photographs of the site, bottom of excavation, and removed tanks;

(6) the results of an inspection of the tank and piping for corrosion;

(7) a site sketch that, at a minimum, shows

(A) locations of all known present and past USTs, piping and pump islands, including UST identification numbers assigned by ADEC;

(B) distances from tanks to nearby structures;

(C) property line locations;

(D) sampling locations and depths and corresponding sample ID numbers;

(E) any release sites;

(F) any free product sites;

(G) scale; and

(H) a north arrow.

When appropriate, the site sketch should include the following relevant features:

(1) a description of the size of the excavation;

(2) field instrument readings;

(3) location of stockpiled soils;

(4) depth, width, and type of backfill material used to surround tanks and piping;

(5) soil types;

(6) utility trenches;

(7) wells within 100 feet;

(8) depth to groundwater or seasonal high groundwater level; and

(9) surface drainages, including potential hydraulic connections with groundwater.

4.3 Pre-Sampling Activities

Before conducting field sampling activities, the site background information must be collected and recorded, the site conditions must be compiled as provided in Sections 4.3.1 and 4.3.2 of this chapter, and the necessary notifications must be made to agencies as provided in Section 4.3.3 of this chapter.

4.3.1 Site Background

Before beginning field work, the following information must be collected and recorded:

(1) the names, addresses, and telephone numbers of the owner, operator, and businesses on the site;

(2) for rural areas, the quarter section, township, and range of the site;

(3) locations of all present and past USTs, piping, and pump islands;

(4) a description of known UST systems, including capacity, dimension, age, and material of construction and location and types of fill and vent pipes, valves, and connectors;

(5) history of types of products stored in the tanks;

(6) history of known releases and available data from previous soil or groundwater sampling at the site;

(7) type and classification of native soil;

(8) location of wells within 100 feet of the site;

(9) surface waters and wetlands in the immediate vicinity of site;

(10) depth to groundwater or seasonally high groundwater level;

(11) property line locations;

(12) distances from tanks to nearby structures; and

(13) type and location of below ground utility lines that could create pathways for contaminant migration.

In addition, where relevant and practical, the following information on the site must be collected and recorded:

(1) location of each hold-down pad or anchoring system, if any;

(2) the name of the contractor who installed the tank, if known;

(3) dates of each installation and upgrade;

(4) performance history, including repair records, inventory records, tightness testing records, leak detection system records, or records of water pullouts;

(5) depth and width of backfill area and type of backfill material used to surround tanks and piping;

(6) surface drainage characteristics, including potential hydraulic connections with groundwater;

(7) location of other nearby USTs, either active or inactive, or other potential sources of contamination; and

(8) previous site uses, including historical waste handling procedures.

4.3.2 Surface Observation of Site Conditions

An observation of the site's surface must be conducted before sample collection to assist in determining field sampling approaches and locations. Activities that must be completed during this observation include:

(1) locating the aboveground components of each UST;

(2) confirmation of the amount of fuel currently in each tank;

(3) determination of tank size;

(4) observation for aboveground utilities;

(5) underground utility locations (contact utility location centers where available);

(6) visual inspection for surface indications of releases;

(7) if practical and no safety hazard exists, check for odor of petroleum in nearby structures (basements); and

(8) check sumps and access manholes for evidence of pump leakage.

Key areas that must be observed for surface indications of a release include:

(1) vent pipes and fill holes;

(2) pavement depressions, buckling, cracks, or patches that could indicate that subsurface problems have historically occurred;

(3) cracks or stains at base of pumps; and

(4) evidence of stressed vegetation that may have resulted from a release or spill.

The results of the site observations must be recorded in a field log book or other appropriate document.

4.3.3 Notification to Agencies

Notification to ADEC, local governments, and fire departments is required before any site assessment work is performed for closure or change-in-service and is subject to the requirements of 18 AAC 78.085.

4.4 Field Screening

Field screening is the use of portable devices capable of detecting petroleum contaminants on a real-time basis or by rapid field analytical technique. Field screening must be used to help assess the following locations where contamination is most likely to be present:

Tank Area

- areas of suspected or obvious contamination;
- adjacent to and below all fill and vent pipes;
- excavation sidewalls below the tank midline;
- one representative sample for at least every 100 square feet of excavation bottom

Piping Run

- areas of suspected or obvious contamination;
- below piping joints, elbows, connections, and damaged piping components; if these locations are unknown then screening must occur below original level of piping at 10 foot-intervals; the 10-foot interval is chosen because pipe sections commonly used are 10-foot lengths and because of limits of detection of soil gas vapors from the release source;

- adjacent to and below all dispensers.

When possible, field screening samples should be collected directly from the excavation or from the excavation equipment's bucket. If field screening is conducted only from the equipment's bucket, then a minimum of one field screening sample must be collected from each 10 cubic yards of excavated soil. If instruments or other observations indicate contamination, soil must be separated into stockpiles based on apparent degrees of contamination. At a minimum, soil suspected of contamination must be segregated from soil observed to be free of contamination. Two levels of field screening procedures are:

(1) use of field screening devices to perform synoptic surveys of potentially contaminated areas to determine the approximate locations containing contaminants (qualitative screening); and

(2) use of field screening devices to provide a semi-quantitative estimate of the amount of contaminant present at a specific location (semi-quantitative screening).

4.4.1 Field Screening Devices

Many field screening instruments are available for detecting petroleum contaminants in the field on a rapid or real-time basis. Acceptable field screening instruments must be suitable for the contaminant being screened. The procedure for field screening using photoionization detectors (PIDs) and flame ionization detectors (FIDs) is described in Section 4.4.2 of this chapter. If other instruments are used, a description of the instrument or method and its intended use must be provided to ADEC. Whichever field screening method is chosen, the accuracy of the method must be verified throughout the sampling process through use of appropriate standards to match the use intended for the data. Unless ADEC indicates otherwise, wherever the requirement for field screening is stated in this chapter, instrumental or analytical methods of detection must be used, not olfactory or visual screening methods.

4.4.2 Headspace Analytical Screening Procedure for Field Screening (Semi-Quantitative Field Screening)

The most commonly used field instruments for UST site assessments in Alaska are FIDs and PIDs. The following headspace screening procedure to obtain and analyze field screening samples must be adhered to when using FIDs and PIDs:

(1) partially fill (one-third to one-half) a clean jar or clean Ziploc bag with the sample to be analyzed; total capacity of the jar or bag may not be less than eight ounces (app. 250 ml), but the container should not be so large as to allow vapor diffusion and stratification effects to significantly affect the sample;

(2) if the sample is collected from a split spoon, it must be transferred to the jar or bag for headspace analysis immediately after opening the split-spoon; if the sample is collected from an excavation or soil pile, it must be collected from freshly uncovered soil;

(3) if a jar is used, its top must be quickly covered with clean aluminum foil or a jar lid; screw tops or thick rubber bands must be used to tightly seal the jar; if a ziplock bag is used, it must be quickly sealed shut;

(4) headspace vapors must be allowed to develop in the container for at least 10 minutes but no longer than one hour; containers must be shaken or agitated for 15 seconds at the beginning and end of the headspace development period to assist volatilization; temperatures of the headspace must be warmed to at least 40° F (approximately 5° C), with instruments calibrated for the temperature used;

(5) after headspace development, the instrument sampling probe must be inserted to a point about one-half the headspace depth; the container opening must be minimized and care must be taken to avoid uptake of water droplets and soil particulates;

(6) after probe insertion, the highest meter reading must be taken and recorded, which normally will occur between two and five seconds after probe insertion; if erratic meter response occurs at high organic vapor concentrations or conditions of elevated headspace moisture, a note to that effect must accompany headspace data;

(7) calibration of PID and FID field instruments must follow the procedures outlined in Section 7.1 of this chapter (Calibration and maintenance of field instruments); and

(8) all field screening results must be documented in the field record or log book.

4.5 Determining Sample Locations

The locations and numbers of laboratory samples to be taken depend on the requirements of 18 AAC 78 for the specific type of sampling activity. The results of field screening must be used to determine the location from which to obtain samples. Samples must be obtained from locations that field screening and observations indicate are most heavily contaminated. A positive field screening result is one in which any deflection in the meter reading occurs at locations where samples are required. Samples analyzed with field screening devices may not be substituted for required laboratory samples. Specific types of sampling activity are as follows:

(1) site assessment for a UST closed in place (18 AAC 78.090);

(2) site assessment for a UST that has been removed (18 AAC 78.090);

(3) site assessment for temporary closure, or change in service, of a UST (18 AAC 78.090);

(4) investigating a suspected release (18 AAC 78.200 - 18 AAC 78.235);

(5) release investigation (18 AAC 78.235); and

(6) documentation that corrective actions have met applicable cleanup standards for soil (18 AAC 78.610) and water (18 AAC 78.620) through final verification sampling.

Within the constraints for sampling locations listed above, laboratory samples must be taken where contamination is most likely to be present.

4.5.1 Sample Locations for Contaminated Untreated Stockpiles

As noted in Section 4.4 of this chapter (Field screening), soils must be segregated during excavation based on apparent degrees of contamination. Soils must be stockpiled in accordance with 18 AAC 78.274.

Characterizing stockpiled soil is necessary to determine whether treatment or disposal of the soil is needed, to assist with selection of treatment or disposal methods, and to establish baseline data for use in evaluating the effectiveness of treatment.

To determine if untreated stockpiled soils can be disposed or considered not contaminated, stockpiled soils must be characterized by using

(1) field screening; at least one soil sample must be obtained from each 10 cubic yards of stockpiled soil for field screening purposes; samples must be obtained from various depths in the pile, but none less than 18 inches beneath the exposed surface of the pile; field screening must follow the procedures outlined in this section and results must be documented in a site log book; and

(2) the number of grab samples collected from each stockpile as required by 18 AAC 78.605(c).

4.5.2 Alternative Sample Collection Procedures

Alternative sampling collection procedures, such as Cone Penetrometer Testing, HydroPunch, and Borehole Geophysical Logging may be used to determine soil hydrogeologic characteristics, contaminant distribution, and contaminant concentration.

These procedures may be useful, with proper evaluation, in providing essential data to assess and delineate the extent of contamination during site characterizations, release investigations, and corrective actions. These alternative procedures may not be used in collecting samples for final verification during site assessment or corrective action.

4.5.3 Sample Locations for Treated Excavated Soils

To determine if excavated soil has been treated, final corrective action verification samples must be from the location and depth of areas showing the highest levels of contamination during field screening.

Unless otherwise approved by the ADEC project manager, at least one field screening sample must be obtained from each 10 cubic yards of treated soil. Field screening samples must be obtained from various depths, but not less than 18 inches beneath the exposed surface of the soil. Field screening must follow the procedures outlined in this section and the results must be documented in a site log book.

The number of grab samples collected from the treated soil must be as required by 18 AAC 78.605(b).

4.6 Collecting Soil Samples

As required by 18 AAC 78, the following procedures must be used to collect soil samples for laboratory analysis:

(1) unless otherwise approved by ADEC, all laboratory soil samples must be grab samples and may not be composited before analysis, except that soil samples for total arsenic, cadmium, chromium, and lead that are for screening purposes may be composited in the field or in the laboratory before analysis;

(2) soil samples taken directly from the surface of excavations must be obtained from freshly uncovered soil; a minimum of six inches of soil must be removed immediately before collection, and the sample must be obtained from the newly uncovered soil; if the excavation has been open for longer than one hour, at least 18 inches of soil must be removed immediately before collection;

(3) soil samples collected from excavation equipment buckets must be obtained from the center of the bucket and away from the bucket sides; at least six inches of soil must be removed immediately before collection;

(4) if soil samples are collected from a soil boring, samples should be collected using a hollow stem auger and split spoon sampler or Shelby tube; using an auger, the drill hole must be advanced to the desired depth; then the center rods of the auger must be withdrawn from the drill hole and the plug and pilot bit removed from the center rods; the sampler must be attached to the correct length of drill rod and must be driven ahead of the auger flights in order to collect a relatively undisturbed sample; after the split spoon or Shelby tube has been retrieved back out of the boring, the desired sample section must be immediately removed from the sampling device; only soil from the middle portion of the spoon may be used for samples; soil from the very ends of the spoon must be discarded as they often contain disturbed soils; a clean sampling tool must be used to quickly collect the sample from the undisturbed portion with a minimum of disturbance and the sample container must be quickly capped, sealed, and labeled; and

(5) soil samples for all parameters listed in Table 1 must be collected in accordance with method specifications.

Alternative methods to obtain soil samples may be used only if the methods have been approved by ADEC before sampling.

The following steps must be taken to minimize collection errors:

(1) all samples must be collected with disposable or clean tools that have been decontaminated as outlined in Section 4.8 of this chapter (Decontamination of field equipment);

(2) disposable gloves must be worn and changed between sample collections;

(3) sample containers must be filled quickly;

(4) soil samples must be placed in containers in the order of volatility; for example, volatile organic aromatic samples must be taken first, gasoline range organics next, heavier range organics next, and soil classification samples last;

(5) containers must be quickly and adequately sealed, and rims must be cleaned before tightening lids; tape may be used only if known not to affect sample analysis;

(6) sample containers must be labeled as outlined in Section 4.9.2 of this chapter (Labeling sample containers);

(7) containers must immediately be preserved according to procedures in Section 4.9.1 of this chapter (Sample containers); unless specified otherwise, at a minimum, the samples must be immediately cooled to 4±2°C and this temperature must be maintained through delivery to laboratory until samples are analyzed.

If groundwater is encountered while soil sampling, the provisions of 18 AAC 78.090 must be followed concerning sampling of the groundwater interface.

4.7 Obtaining Groundwater Samples from Borings/Wells

Groundwater samples might be required if contamination of the groundwater is suspected. Water sampled directly from an excavation is not necessarily representative of normal groundwater conditions and will not be evaluated as a representative groundwater sample. In such cases, installation and sampling of a groundwater monitoring well might be required, as determined by ADEC under 18 AAC 78.615.

4.7.1 Installing Groundwater Monitoring Wells

Unless otherwise directed by ADEC, if groundwater monitoring wells are required, the installation must be as required by 18 AAC 78.615(b), and the following procedures must be used:

(1) if the direction of groundwater flow is known, at least three monitoring wells must be installed and sampled, one upgradient and two downgradient of the potential contamination source;

(2) if the direction of groundwater flow is unknown, it is recommended that the number of wells installed be sufficient to characterize the groundwater flow using horizontal and vertical control measures; at least three monitoring wells must be installed and sampled;

(3) well drilling equipment must be decontaminated as outlined in Section 4.8 of this chapter (Decontamination of field equipment) before drilling at each new location; and

(4) wells should be driven with a hollow stem auger or cable drill; if other methods are used, ADEC approval must be obtained before the well is installed.

The following details of well construction must be recorded in the field record:

(1) well location, determined by reference to site bench mark;
(2) total depth of boring;
(3) depth to groundwater at time of drilling;
(4) diameter of boring;
(5) depth to top and bottom of screened interval;
(6) diameter of screened interval;
(7) diameter of casing;
(8) well construction material;
(9) depth of packed filter interval;
(10) depth and thickness of seals;
(11) type of surface cap;
(12) names of drilling firm and drilling personnel; and
(13) soil log completed using the Unified Soil Classification System, U. S. Soil Conservation Service classification system, or another similar soil classification system.

Under 11 AAC 93.140, a log of the well must be submitted to the Alaska Department of Natural Resources (ADNR) within 45 days after installing a well. The log must include the location and depth of the well, an accurate log of the type and depths of soil and rock formations encountered, the depth and diameter of the casing, screened intervals, well completion materials, and the static water level in the well. Well logs should be submitted to ADNR/Mining and Water Management, P.O. Box 107005, Anchorage, AK 99510; (907) 762-2165. Well logs for sites within the northern region should be sent to ADNR/Division of Water, 3700 Airport Way, Fairbanks, AK 99706; (907) 451-2772. Well log reporting forms are available from the ADNR/Alaska Hydrologic Survey at the above addresses.

4.7.2 Sampling Groundwater Monitoring Wells

If multiple wells are sampled, the wells upgradient of the site should be sampled first to minimize cross-contamination. Before sampling wells, the depth to groundwater must be determined by manual or electronic means. Measurement devices must be calibrated before use to an accuracy of at least 0.02 foot.

4.7.2.1 Determining Well Depth and Presence of Non-Aqueous Phase Liquids

Before sampling a monitoring well, the column of water in the well casing must be checked for the presence of nonaqueous phase liquids, including free petroleum products that might be floating on top of the water or in a separate layer at the bottom of the casing. Nonaqueous phase liquids are identified by:

(1) carefully lowering a clean bailer, in a manner that will create minimum disturbance, into the well before purging and observing the liquids removed from the top and the bottom of the water column;

(2) using a paste type of detector with ingredients that will not lead to cross-contamination; or

(3) using an electronic device designed to detect nonaqueous liquids and to measure the thickness of the nonaqueous layer.

If free product is present, the well must be bailed or pumped to remove the product and must be monitored to evaluate the recharge rate.

4.7.2.2 Well Purging

Monitoring wells must be purged before sampling unless otherwise approved by ADEC, using the following procedure (or an equivalent):

(1) at least three casing volumes of water must be removed from the well before sample collection or, for low yield wells, until the well bore is evacuated; or instead of purging three casing volumes, measure the purge water temperature, pH, and conductivity until these parameters are stable to within 10 percent variability between measurements;

(2) all purged water must be carefully collected, containerized, and stored for proper disposal pending evaluation of groundwater sample analyses; the results of the analyses and the applicable federal, state, and local water quality criteria must determine the acceptable method for disposal of the purge water; and

(3) upgradient wells should be purged before downgradient wells to help minimize possible cross contamination.

4.7.2.3 Collecting Groundwater Samples with Bailers

If a bailer is used to collect samples, the following procedure must be used:

(1) after purging the well, sufficient time must be allowed for the well to equilibrate and fines to settle; if full recovery exceeds two hours, samples must be extracted as soon as sufficient volume is available;

(2) the water level must be remeasured after purging has occurred and water level has returned to the static level;

(3) if decontaminated equipment is used to collect the water sample, the sampler must be rinsed with analyte-free distilled or deionized water; a portion of this rinsate must be collected into a container appropriate for the most volatile analyte suspected (typically BTEX); this equipment blank (also termed decontamination blank) must be contained, preserved, and analyzed according to the procedures outlined in this chapter for that analyte;

(4) bailers must be made of glass, Teflon, stainless steel, other suitable materials, or of disposable materials such as Teflon or polyethylene; polyvinyl chloride (PVC) bailers are not acceptable for sampling volatile organic compounds; all bailers must be decontaminated as outlined in Section 4.8 of this chapter (Decontamination of field equipment);

(5) the bailer must be fitted with a new bailer line for each well sampled; the bailer and line may be handled only by personnel wearing decontaminated or disposable gloves;

(6) the bailer should be slowly lowered to minimize disturbance of the well and water column; the bailing line should be prevented from contact with the outside of the well, equipment, and clothing; special care must be taken to minimize disturbance of the water table interface when inserting the bailer;

(7) samples must be obtained as close as possible to the water level/air interface, unless analysis indicates that contamination is at a different depth;

(8) grab samples must be obtained;

(9) the bailer must be slowly lifted and the contents transferred to a clean sample container with a minimum of disturbance and agitation to prevent loss of volatile compounds; if different analytes are sampled, samples must be transferred to containers in the order of their volatility; headspace in the sample container must be minimized by filling the sample jar until a positive meniscus is present;

(10) containers must be quickly and adequately sealed; container rims and threads must be cleaned before tightening lids; unless otherwise specified, Teflon-lined screw caps must be used to seal the jar;

(11) sample containers must be labeled as outlined in Section 4.9.2 of this chapter (Labeling sample containers); and

(12) containers must be preserved immediately according to procedures in Section 4.9.1 of this chapter (Sample containers). Unless specified otherwise, at minimum the samples must be immediately cooled to 4±2°C and this temperature must be maintained through delivery to the laboratory until the samples are analyzed.

4.7.2.4 Alternative Methods of Collecting Groundwater Samples

If a positive displacement pumping system or another system is used instead of a bailer, it must be clean or decontaminated as described in Section 4.8 of this chapter (Decontamination of field equipment). Disturbance of the well, water column, and samples must be minimized. Only grab samples may be obtained, not composite samples. Samples must be obtained as close as possible to the water level/air interface unless analysis indicates that contamination is at a different depth. If different analytes will be sampled, samples must be transferred to containers in the order of volatility. Volatiles must be collected first, followed, in order, by gasoline range organics, heavier range organics, and metals. Container headspace must be minimized by filling the sample jar until a positive meniscus is present. Containers must be quickly and adequately sealed. Rims must be cleaned before tightening lids. Sample containers must be labeled as outlined in Section 4.9.2 of this chapter (Labeling sample containers). Containers must be preserved immediately according to procedures in Section 4.9.1 of this chapter (Sample containers). Unless specified otherwise, at a minimum the samples must be immediately cooled to 4±2°C and this temperature must be maintained through delivery to laboratory until the samples are analyzed.

4.8 Decontamination of Field Equipment

Decontamination of personnel, sampling equipment, and containers before and after sampling must be used to ensure collection of representative samples and to prevent the potential spread of contamination. Decontamination of personnel prevents ingestion and absorption of contaminants and must be done with a soap and water wash and deionized or distilled water rinse.

All previously used sampling equipment must be properly decontaminated before sampling and between sampling locations to prevent introduction of contamination into uncontaminated samples and to avoid cross-contamination of samples. Cross-contamination can be a significant problem when attempting to characterize extremely low concentrations of organic compounds or when working with soils that are highly contaminated.

Clean, solvent-resistant gloves and appropriate protective equipment must be worn by persons decontaminating tools and equipment.

4.8.1 Decontamination of Soil Sampling Tools

At a minimum, soil sampling tools must be cleaned and decontaminated by the following three-step procedure:

(1) tools must be scrubbed with a stiff brush in a solution of hot water and laboratory-grade, critical cleaning detergent such as Alconox or a similar product;

(2) tools must be rinsed twice in clean water; and

(3) tools must be thoroughly rinsed with distilled or deionized water.

If concentrated petroleum products or highly contaminated soils are encountered during sampling, an appropriate solvent should be used to remove heavy petroleum residues from the sampling tools. This must be followed by the minimum cleaning procedure outlined above. If a solvent is used, it must be properly collected, stored, and disposed of according to acceptable hazardous waste disposal guidelines.

4.8.2 Decontamination of Water Sampling Tools

Drill auger sections, split spoons, and drive hammers that come in contact with bore holes must be cleaned before use and between borings using the following three-step procedure:

(1) tools must either be

(A) scrubbed with a stiff brush in a solution of water and laboratory grade, critical cleaning detergent such as Alconox or a similar product; or

(B) cleaned with high pressure hot water or steam and a laboratory grade, critical cleaning detergent;

(2) tools must be rinsed twice in clean water; and

(3) tools must be thoroughly rinsed with distilled or deionized water.

Steel tapes, well sounders, transducers, and water quality probes must be rinsed with clean water and then with deionized water.

Reusable bailers must be washed in Alconox or another laboratory grade, critical cleaning detergent solution, rinsed twice in clean water, and then rinsed with distilled or deionized water.

4.8.3 Excavation Equipment

Excavation equipment must be clean before each site excavation begins.

4.8.4 Cleaning Sample Containers

Sample containers must be cleaned and prepared by an analytical laboratory. The exterior of sample containers must be cleaned after the samples are collected and the container lids are tightly sealed. Solvents may not be used for this procedure because of the potential to contaminate the sample.

4.8.5 Disposal of Washwater, Rinsate, and Disposable Sampling Tools

Washwater and rinsate solutions must be collected in appropriate containers and disposed of properly in accordance with federal, state, and local regulations. Bailing strings and wires and other disposable sampling tools must be properly discarded after use at each well.

4.9 Sample Containers and Holding Conditions

Containers used to collect samples must be chosen based on their suitability for the analyte of interest and may vary according to the laboratory contracted to perform the analysis. Preservation methods and maximum holding conditions are method-specific and must be adhered to.

4.9.1 Sample Containers

Most containers should be glass jars with Teflon-lined lids. Sample jars of the acceptable type of material, size, and type of lid are shown in Table 1. Use of sample containers must conform to these specifications. Also shown in that table are the preservation methods and maximum holding times for each analyte of interest.

All sample containers must be inspected before transit to the site to ensure that they have undamaged lids and are tightly sealed. Jars must be placed into containers that are secured to prevent damage or tampering in transit to the site. Containers and lids must be re-inspected at the job site; containers that have lost lids or that have been damaged may not be used for sample containment.

4.9.2 Labeling Sample Containers

Indelible, waterproof ink must be used to label sample containers. Labels, if used, must be securely fastened to the container. All information entered onto the label or container must be duplicated in the field record or log book. Information on the containers or labels must include:

(1) unique identifying number assigned to the sample for laboratory analysis;

(2) date and time of collection;

(3) name of person collecting the sample;

(4) each intended laboratory analysis for the sample;

(5) preservation method.

If possible, the following information should also be included on the container or label:

(1) project name and location of sample;

(2) maximum holding time (or date by which sample must be extracted and analyzed).

4.9.3 Holding Times, Conditions, and Methods of Preservation

Sample handling, transport, and analysis must be arranged so that the holding times and conditions shown in Table 1 are met. Also, volatile compounds must be extracted and analyzed as quickly as practical after collection.

Appropriate acidic preservation of samples must be provided if required in Table 1.

4.9.4 Site Safety Plan

The qualified environmental professional is responsible for a site safety plan for construction activities and activities within a confined space.

SECTION 5. SAMPLE TRANSFER LOG

5.1 Sample Transfer Log

The requirements in this section apply to all sampling associated with a site assessment, from initial investigation through all final verification samples.

A transfer log is required for each sample taken, including all associated field quality control (QC) samples. A transfer log consists of a document or label that physically accompanies each sample bottle and sample, or each batch of bottles and samples, and that provides for the name of each person assigned control of the sample and the period covered by each person's assignment. Sufficient space must be provided on the form to accommodate several different control persons, the name of their respective organization or agency, and specific spaces for commercial carriers.

The laboratory receiving samples must process the samples using control procedures documented in its approved Quality Assurance (QA) Manual and Standard Operating Procedures. This section does not apply to internal laboratory procedures.

SECTION 6. ANALYTICAL PROCEDURES

6.1 Field Screening Procedures

Use of field screening analyses with Photo Ionization Detectors (PIDs) and Flame Ionization Detectors (FIDs) must follow the relevant procedures outlined in Section 4 of this manual (Sampling Procedures) and Section 7 of this manual (Calibration and Maintenance of Field Equipment). If other instruments are used, a written description of that use must be provided to ADEC by the qualified environmental professional.

6.2 Identification of Laboratory Conducting Analyses

Only results from a laboratory certified by ADEC will be accepted by ADEC for use in reports prepared under this chapter. ADEC will not accept laboratory results unless the laboratory's current state laboratory UST identification number accompanies those results.

6.3 Determination of Analyses for Petroleum Hydrocarbons

Unless approval to deviate from these specifications is obtained in advance from ADEC, selection and use of all laboratory analyses must conform to the provisions of Table 2A and appropriate sections of this chapter. Table 2A indicates which product is to be tested for each petroleum range using Alaska Series Methods, AK 101, AK 102, AK103, AK101AA, AK102AA, and AK103AA and for the various indicator compounds listed in Table 2B, using methods from EPA's *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846. Methods are specified for each analyte in Table 1, Part A and B of this Manual. The

identity of a released refined petroleum product is assumed to be unknown unless a laboratory analysis shows that a contaminant is only a gasoline or only a nongasoline refined product, unless this requirement is waived by ADEC.

The soil cleanup standards for petroleum in 18 AAC 75.340 are based on gas chromatographic analytical measurements corresponding to a specific measured range of petroleum hydrocarbons as follows:

(1) gasoline-range organics: light-range petroleum products such as gasoline, with petroleum hydrocarbon compounds corresponding to an alkane range from the beginning of n-hexane (C_6) to the beginning of n-decane (C_{10}) and with a boiling point range between approximately 60 - 170 degrees Celsius;

(2) diesel-range organics: mid-range petroleum products such as diesel fuel, with petroleum hydrocarbon compounds corresponding to an alkane range from the beginning of n-decane (C_{10}) to the beginning of n-pentacosane (C_{25}) and with a boiling point range between approximately 170 - 400 degrees Celsius; and

(3) residual-range organics: heavy-range petroleum products such as lubricating oils, with petroleum hydrocarbon compounds corresponding to an alkane range from the beginning of n-pentacosane (C_{25}) to the beginning of n-hexatriacontane (C_{36}) and with a boiling point range between approximately 400 - 500 degrees Celsius.

If it can be documented that only one type of product was stored or distributed during the operational life of a facility, a waiver may be requested from ADEC for the requirement to determine the identity of the product, in accordance with 18 AAC 78.600(d). The information collected in the examination of the site background (Section 4.3.1 of this chapter) will be used to determine if a waiver should be sought.

If leaded gasoline is a potential contaminant at the site, a preliminary laboratory analysis for lead might be required. The ADEC project manager must be contacted for this determination.

Table 2A
Determination of Sampling and Laboratory Analysis for Soil(s) and Groundwater (GW)

Petroleum Product	C6-C10 GRO	C10-C25 DRO	C25-C36 RRO[6]	BTEX Constituents	PAH[1, 2, 7]	Metals and Solvents
Leaded Gasoline	S & GW			S & GW	S & GW	(S & GW)[5]
Aviation Gasoline	S & GW			S & GW	S & GW	(S & GW)[5]
Gasoline	S & GW			S & GW	S & GW	
JP-4	S & GW	S & GW		S & GW	S & GW	
Diesel #1/Arctic Diesel	S & GW	S & GW		S & GW	S & GW	
#2 Diesel		S & GW		S & GW	S & GW	
#3 - #6 Fuel Oils		S & GW	S & GW	S & GW	S & GW	
JP-5, JP-8, Jet A	S&GW	S & GW		S & GW	S & GW	
Waste Oil/Used oil	S & GW	S & GW	S & GW	S & GW	S & GW	(S & GW)[3,4]
Kerosene	S & GW	S & GW		S & GW	S & GW	
Unknown	S & GW	S & GW	S & GW	S & GW	S & GW	(S & GW)[3,4]

Legend:
GRO = Gasoline Range Organics {using AK 101 or AK 101AA}
DRO = Diesel Range Organics {using AK 102 or AK 102AA}
RRO = Residual Range Organics {using AK 103 (for soil) or AK 103AA (for soil and groundwater)}
BTEX = refers to individual indicator compounds to be analyzed: benzene, toluene, ethylbenzene, and total xylenes.
PAH = acenaphthene, anthracene, benzo-a-anthracene, benzo-a-pyrene, benzo-b-fluoranthene, benzo-k-fluoranthene, chrysene, dibenzo-a,h-anthracene, fluorene ideno-123-cd-pyrene, naphthalene, and pyrene

[1] PAH analysis for soils would be required for all petroleum releases, unless the sum of the applicable soil cleanup concentrations based on laboratory results in accordance with Table 2, for individual petroleum hydrocarbon fractions or ranges determined for the site by applying the corresponding Method 2 – 4 referenced in 18 AAC 75.340 is equal or less than 500 mg/kg. PAH analysis is not required for Method 1 referenced in 18 AAC 75.340.

[2] All of the PAH indicator compounds listed in Table 2A would be required for all petroleum products except gasoline and JP-4 fuel spill analysis which would be limited to the naphthalene only, unless the project manager requires otherwise.

[3] Metals analysis, except where noted, would include: arsenic, barium, cadmium, chromium, lead, nickel, and vanadium.

[4] Volatile chlorinated solvents and other additives listed in Table 2A must be performed if required by the project manager.

[5] Metal analysis for lead only must be performed if required by the project manager.

[6] For sampling groundwater for RRO use the "aromatic residual range organics" fraction parameter method listed in Table 1, Part B, of this manual.

[7] PAH analysis for groundwater is required if there is a requirement for PAH analysis in soil.

TABLE 2B
Indicator Compounds
For Petroleum Contaminated Sites

Volatiles (BTEX)

benzene
toluene
ethyl benzene
total xylene

*Polynuclear Aromatic Hydrocarbons (PAHs)** - **Carcinogens***

benzo(a)pyrene
chrysene
indeno(1.,2,3-cd)pyrene
benzo(k)fluoranthene
benzo(b)fluoranthene
benzo(a)anthracene
dibenzo(a, h)anthracene

*Polynuclear Aromatic Hydrocarbons (PAHs)** - **Noncarcinogens**

anthracene
acenaphthene
pyrene
naphthalene
fluorene

Metals as required on a case by case basis

Arsenic
Barium
Cadmium
Chromium
Lead
Nickel
Vanadium

Others as needed on a case by case basis

ethylene dibromide (EDB)
1,2 dichloroethane (EDC)
methyl 1 tert-butylether (MTBE)
volatile chlorinated solvents

SECTION 7. CALIBRATION AND MAINTENANCE OF FIELD EQUIPMENT

Calibration and proper maintenance of field instruments is critical to obtaining acceptable data. Improper calibration or failure of an instrument in the field might result in improper choice of sample locations, failure to detect contamination, and inefficient and inadequate segregation of clean soils from contaminated soils and, thus, potentially much higher disposal or treatment costs.

7.1 Calibration and Maintenance of Field Instruments

To ensure that field instruments will be properly calibrated and remain operable in the field, the procedures set out in this section must be used.

7.1.1 Calibration

(1) If PID and FID field instruments are used, instruments must be calibrated before each testing session to yield "total organic vapors" in parts per million to a benzene equivalent. The PID instrument must be operated with a lamp source that is able to detect the contaminants of concern, operates at a minimum of 10.6 eV, and is capable of ionizing those contaminants of concern.

(2) Field instruments must be calibrated onsite.

(3) All standards used to calibrate field instruments must meet the minimum requirements for source and purity recommended in the instrument's operation manual.

(4) If the instrument's operation manual recommends specific calibration requirements for other criteria in calibrating the instrument (such as pH, conductivity, temperature, etc.), those criteria must be adhered to.

(5) Acceptance criteria for calibration must be determined depending on the potential contaminant(s) and must be within the limits set in the manufacturer's operations manual.

(6) The dates, times, and results of all calibrations and repairs to field instruments must be recorded in the field record and in the instrument's log.

(7) All users of the instrument must be trained in the proper calibration and operation of the instrument and must be required to read the operation manual before initial use.

7.1.2 Maintenance

(1) At a minimum, operation, maintenance, and calibration must be performed in accordance with the instrument manufacturer's specifications.

(2) All users of the instrument must be trained in routine maintenance, including battery and lamp replacement, lamp and sensor cleaning, and battery charging.

(3) Each instrument's operation and maintenance manual must be present at the site.

(4) Field instruments must be inspected before departure for the site and on site.

(5) Instrument battery charge must be inspected far enough ahead of time to bring the instrument up to full charge before departure for the site.

(6) At a minimum, a source of extra batteries and lamps (if applicable) must be readily available.

SECTION 8. DATA REDUCTION, VALIDATION, AND REPORTING

Data reduction describes the handling of standard, sample, and blank results; how blank analysis results must be used in calculating final results; examples of data sheets; and positions of persons responsible for data reduction.

Data validation is the systematic process of reviewing the data against criteria to assure the adequacy of the data.

Data reporting details how reports will be generated and what must be included in them.

8.1 Responsibility for Laboratory Data

The laboratory must conduct these activities on, and be responsible for, data that is processed within the laboratory. The owner or operator shall ensure that the qualified environmental professional reviews final laboratory data reduction, validation, and reporting and

(1) selects a laboratory based on demonstrated ability to properly reduce, validate, and report data;

(2) verifies laboratory approval status; a list of approved laboratories is available from ADEC; and

(3) reviews all laboratory results and performance to ensure that the objectives of this chapter are met; if questions or problems arise with the laboratory analysis, the owner or operator shall ensure that the qualified environmental professional takes appropriate corrective actions as outlined in Section 10 of this chapter (Corrective actions); significant problems must be reported to ADEC.

8.2 Final Data Reduction

Data reduction is the compilation, condensation, and simplifying of information into a more easily understood product. The owner or operator shall ensure that the product furnished by the laboratory is examined, using standard statistical methods, by a qualified environmental professional or QA officer with the education, professional experience, and training necessary to meet a project's technical and regulatory requirements, and that this professional conducts or supervises any further reduction of field and laboratory data into the final report.

8.3 Final Data Validation

The owner or operator shall ensure that validation of field data by the qualified environmental professional occurs before the data are inserted into a report. The results of the evaluations discussed in this subsection must be documented in the report, must be used in data interpretation, and may be used to initiate corrective actions outlined in Section 10 of this chapter (Corrective actions).

8.3.1 Validation of Field Reports

The owner or operator shall ensure that the qualified environmental professional or QA officer examines all information collected through the field documentation process (Section 4.2 of this chapter). This information must be checked for

(1) completeness;

(2) accuracy (for example, transcription errors, internal consistency);

(3) unexpected results, with accompanying possible explanations;

(4) adherence to sampling procedures outlined in Section 4 of this chapter;

(5) comparison of field instrument results with laboratory results.

8.3.2 Review of Laboratory Data

The owner or operator shall ensure that the qualified environmental professional pays special attention to the establishment of detection and control limits and deviations from them; if deviations are identified, they must be flagged for discussion in final reports and possible corrective action. Examples of limits and deviations include

(1) any limits outside of the acceptable range;

(2) lack of documentation showing the establishment of necessary controls; and

(3) unexplainable trends.

8.3.3 Determining the Final Validity of Samples

Samples collected in accordance with this chapter are considered valid unless otherwise indicated. Samples that are not collected in accordance with this chapter will be considered invalid; in particular, a sample will be considered invalid if

(1) the sample collection was not conducted by a qualified sampler or qualified environmental professional or supervised by a qualified environmental professional as required by 18 AAC 78;

(2) the sample was collected with previously-used tools that were not decontaminated as outlined in this chapter;

(3) the sample was not taken at the location or depth specified by this chapter;

(4) the sample was not taken at a location determined by a correctly calibrated and operated field instrument or by other documented observation to be representative of the most likely areas of contamination;

(5) the sample was collected using a method not listed in this chapter or a method that is inappropriate for the analyte;

(6) the sample was composited before analysis, unless compositing of the sample is explicitly specified by this chapter or approved by ADEC in the workplan required under 18 AAC 78;

(7) the sample jar was not clean before soils or water were deposited into it;

(8) the sample was incorrectly labeled (or not labeled) and field records do not show the location where the sample was collected;

(9) a water sample from a boring or well was not collected in accordance with Section 4.7 of this chapter;

(10) an improper analysis method was performed on the sample;

(11) the analysis of the sample was conducted by a laboratory that was not approved by ADEC at the time of analysis.

8.4 Data Reporting

8.4.1 Information to Be Included in Reports

Reports prepared under this chapter must, at a minimum, contain the following:

(1) the laboratory's data summary as required by Section 8.4.2 of this chapter (Laboratory data reports for samples) for each sample analyzed;

(2) an interpretation of data and sampling results, as required by the tasks discussed in Section 8.3 of this chapter (Final data validation);

(3) a table that contrasts the required field quality control data (discussed in Section 9.1.1 of this chapter) with the limits specified by this chapter (Section 8.4.2, below);

(4) a case narrative for the project;

(5) a separate section or attachment that discusses all deviations from procedures outlined in this chapter and any relevant information compiled from field records or other information required by 18 AAC 78 including a discussion of any deviations from this chapter for any sampling or analytical methods and procedures, whether used by the qualified environmental professional or by the laboratory;

(6) for corrective action sampling activities, a separate section or attachment that discusses all corrective actions taken as required by Section 10 of this chapter, and any other corrective action for other deviations from this chapter including corrective action (such as resubmission of the sample) for sample results that fall within a factor of 2 of the action level after having had corrections for matrix interferences applied (see discussion in Section 10.4 of this chapter--Corrective actions with laboratory);

(7) a summary of the site assessment or release investigation information, provided to the owner or operator on a form available from ADEC (Site Assessment and Release Investigation Summary Form, see Appendix A), or similar format containing the same information; and

(8) other items required for reports by 18 AAC 78.

8.4.2 Laboratory Data Reports for Samples

(a) For each project conducted under this chapter, the owner or operator shall ensure that the qualified environmental professional provides a data transmittal summary for each sample analyzed by the laboratory, including all field and laboratory QC samples, whether the samples are rejected or not. The following items must be submitted in the report:

(1) laboratory name, address, telephone number, fax number (if available), UST Lab ID number, and the name of the person authorizing release of laboratory data;

(2) report date;

(3) type of analysis (gasoline, diesel, etc.);

(4) the analytical and extraction method used and method number (see Tables 1 and 2);

(5) the type of matrix;

(6) the field sample number;

(7) the laboratory sample number;

(8) the UST laboratory identification number assigned by ADEC;

(9) the date sampled;

(10) the date received;

(11) the date extracted and digested;

(12) the date analyzed;

(13) the location of the sample collection point;

(14) the site or project name;

(15) the concentrations of analyte (reported in micrograms per liter for liquids, milligrams per kilogram, dry weight basis for solids);

(16) definitions of any characters used to qualify data;

(17) precision and accuracy values for each sample set, with at least one precision and accuracy evaluation for each set of 20 samples;

(18) the ambient temperature of the interior of the shipping container adjacent to the sample container when received by the laboratory;

(19) a copy of the sample transfer logs for each sample or group of samples;

(20) the analyst's name, signature or initials, and date signed;

(21) the dilution factor;

(22) a narrative summary report for each set of samples (not to exceed 20 samples per set), including a discussion of any significant matrix interferences, low surrogate recoveries, or analyte identifications as appropriate; and

(23) Laboratory Data Report Check Sheet (Appendix B).

(b) The following items must be retained on file by the laboratory for at least ten years after the analysis. They are not required in the report, but must be made available to ADEC upon request:

(1) the UST laboratory identification number assigned by ADEC;

(2) copies of all sample gas chromatogram traces with the attached integration report; copies of the reconstructed ion chromatograms (RIC's) must be provided if performing the analysis by mass spectroscopy; chromatograms must be provided for all samples, method blanks, and daily calibration standard; chromatograms must be identified with a sample identification and the time and date of analysis;

(3) a document containing the date and time for the initial calibration and the standards used to verify instrument settings for the data reported; include the composition and concentration range of standards used to establish and verify maintenance of instrument calibration; and

(4) a document explaining laboratory quality control samples used for the data reported and results obtained; include information concerning surrogates, alkane standard, column performance, matrix spike and matrix spike duplicate samples, blank data, and reference samples.

8.4.3 Submission of Reports to Tank Owner or Operator

All reports must be submitted to the tank owner or operator by a qualified environmental professional as described in Section 2.1 of this chapter (Personnel and responsibilities). If submission of reports to ADEC is required under 18 AAC 78 or by ADEC, the qualified environmental professional must inform the tank owner or operator of the requirement.

SECTION 9. INTERNAL QUALITY CONTROL CHECKS

Required quality control (QC) checks include field QC check samples and laboratory QC samples. Comparison of acceptable tolerances and actually derived values for each required QC element must appear in each project report submitted, as discussed in Section 8.4.1 of this chapter (Information to be included in reports).

9.1 Field Quality Control Checks

This section defines the types of field QC checks that must be used and the circumstances in which each type is to be used. All field QC check samples must be analyzed, the results of the analysis used to calculate data quality indicators, and must be summarized as shown in Table 3 or a similar format. When used, QC measures must be performed, at a minimum, for the most volatile analyte under investigation.

TABLE 3
Example of Field Quality Control Summary

Quality Control Designation	Tolerance	Results This Project
Holding time w/methanol GRO for soil	28 days	
Holding time GRO for water	14 days at 4° ± 2° C	
Holding time to extract DRO for soil	14 days at 4° ± 2° C	
Holding time to extract DRO for water	14 days at 4° ± 2° C	
Holding time to analyze DRO for soil	Less than 40 days	
Holding time to analyze DRO for water	Less than 40 days	
Holding time to extract RRO for soil	14 days at 4° ± 2° C	
Holding time to analyze RRO for soil	Less than 40 days	
Holding time to analyze; BTEX; soil	14 days at 4° ± 2° C or per method requirements	
Holding time BTEX for water	14 days at 4° ± 2° C	
Holding time to extract PAH for soil	14 days at 4° ± 2° C	
Holding time to extract PAH for water	7 days at 4° ± 2° C	
Holding time to analyze PAH for soil	Less than 40 days	
Holding time to analyze PAH for water	Less than 40 days	
Holding time Total VCS for soil	14 days at 4° ± 2° C	
Holding time Total VCS for water	14 days at 4° ± 2° C	
Holding time to extract PCB for soil	14 days at 4° ± 2° C	
Holding time to extract PCB for water	7 days at 4° ± 2° C	
Holding time to analyze PCB for soil	Less than 40 days	
Holding time to analyze PCB for water	Less than 30 days	
Holding time on digestate Total arsenic for soil	6 months max.	
Holding time on digestate Total arsenic for water	6 months max	
Holding time on digestate Total cadmium for soil	6 months max	
Holding time on digestate Total cadmium for water	6 months max	
Holding time on digestate Total chromium for soil	6 months max	
Holding time on digestate Total chromium for water	6 months max	
Holding time on digestate Total lead for water	6 months max	
Completeness	85%	
Field Duplicate	From ADEC project manager	
Decontamination Blank (s)	Less than practical quantitation limit	
Trip Blank (s)	Less than practical quantitation limit	
Methanol Trip Blank	Less than practical quantitation limit	
Field Blank	Less than practical quantitation limit	
Background Sample (s)	Assess background influence on final verification samples	

Legend: BTEX = Benzene, Toluene, Ethyl-benzene, Xylene;
DRO = Diesel Range Organics;
GRO = Gasoline Range Organics;
RRO= Residual Range Organics;
PAH = Polynuclear Aromatic Hydrocarbons; individual indicator PAH compounds
PCB = Polychlorinated Biphenyls;
VCS = Volatile Chlorinated Solvents.

9.1.1 Minimum Field QC Sample Requirements

Table 4 shows the minimum level of sample QC scrutiny that must be applied to field sampling. A description of each type of field QC sample appears in Sections 9.1.2. - 9.1.5 of this chapter. Reference to sets of samples in this and subsequent subsections refers to samples taken from the same site (or, for multiple sampling points within a single project, from the same area within a site that has uniform characteristics such as grain size and organic content) during the same sampling event during a discrete time period. It does not apply to sampling points from different sites, samples taken at significant time differences from each other, nor multiple samples from the same site, but with nonuniform site characteristics.

Table 4. Minimum Quality Control Scrutiny

Minimum Field QC Samples Required	When Required	Allowable Tolerance
Field Duplicate (One per set of 10 samples, minimum of one)	All soil and water samples	Precision set by Project Manager
Decontamination or Equipment Blank (One per set of 20 similar samples, minimum of one)	All soil and water samples Where sampling equipment is decontaminated between samples	Less than the practical quantitation limit listed in Table 1
Trip Blank (One per set of 20 volatile samples, minimum of one)	All water samples Being analyzed for GRO, BTEX, or volatile chlorinated solvents.	Less than the practical quantitation limit listed in Table 1
Methanol Trip Blank (One per set of 20, minimum of one)	All soil samples Being analyzed for GRO, BTEX or volatile chlorinated solvents using AK101or AK101AA field methanol preservation	Less than the practical quantitation limit listed in Table 1
Field Blank (One per set of 20, minimum of one)	Per project specifications. Used for highly contaminated sites with volatile organic contaminants	Less than the practical quantitation limit listed in Table 1

9.1.2 Field Duplicate Sample

Field duplicate samples are useful in documenting the precision (variability) of the sampling process and the site. They are independent samples collected as close as possible to the same point in space and time. They are two separate samples taken from the same source, stored in separate containers, and analyzed independently.

At least one field duplicate must be collected for every 10 samples for each matrix sampled, for each target compound. Duplicate water samples must be collected as close as possible to the same point in space and time and must be collected before any decontamination blanks are collected. Duplicate soil samples must be collected as close as possible to the same point in space and time. All field duplicates must be blind samples and must be given unique sample numbers just like any other field sample. Their collection should be adequately documented. The results from field duplicate samples must be used to calculate a precision value for field sampling quality control.

9.1.3 Decontamination or Equipment Blank

A decontamination or equipment blank is used to determine if contamination occurred from sampling equipment such as pumps and bailers and checks to make sure equipment decontamination procedures have been effective. This blank is a sample of contaminant-free media used to rinse sampling equipment. It must be collected after completion of decontamination procedures and before sampling. Decontamination blanks for water samples must be collected as described in Section 4.7.2 of this chapter (Sampling groundwater monitoring wells). Decontamination blanks for soil samples must be collected in a similar manner. Decontamination blanks would not be required if disposable bailers are used for each sample taken.

If decontamination blanks are required, at least one decontamination blank must be collected and analyzed for each set of water samples that might contain volatiles. In addition, at least one decontamination blank must be collected and analyzed for every 20 soil samples collected each day.

9.1.4 Trip Blank and Methanol Trip Blank

A trip blank is used to document if contamination occurred in the sample containers during shipping, transport, or storage procedures. This blank is a sample of contaminant-free media taken from the laboratory to the sampling site along with each batch of samples and returned to the laboratory **unopened**. An aqueous trip blank would contain organic free water and a methanol trip blank would contain methanol. This type of blank can be especially useful in documenting when trace volatile organic compounds are being investigated. A trip blank would be used for samples being analyzed for all volatile organic compounds such as GRO, BTEX, and volatile chlorinated solvents.

If a trip or methanol trip blank is required, at least one trip or methanol trip blank must accompany each set of 20 samples that might contain volatile organic contaminants.

9.1.5 Field Blank

A field blank is used to document if sample contamination occurred as a result of reagent and/or environmental contamination from contaminated air at the sample location. This blank is especially helpful for highly contaminated sites with volatile organic compounds. A field blank is a sample of contaminant-free media taken from the laboratory to the sampling site and **opened onsite** during the sampling procedure. The field blank is then sealed and appropriately labeled and returned to the laboratory for analysis with the sample batch. The field blank does not replace the trip blank. If required, a field blank must accompany each set of 20 samples destined for volatile organics analysis.

9.1.6 Background Sample

A background sample is optional and is taken to document and assess contaminant baseline or historical information. This sample is collected in an area judged to be free of a site contaminant. A background sample must be collected whenever, in the QA officer's judgment, it is required:

(1) to document the occurrence of naturally occurring organics, especially when their presence might interfere with analytical tests;

(2) to document the presence of contamination by migration of contaminants from off-site or non-UST-related sources; and

(3) in a corrective action or treatment plan.

9.2 Laboratory Quality Control Samples

Laboratory quality control (QC) samples typically accompany the field samples during the laboratory preparation and analysis. The number of laboratory QC samples are dependent on the standard operating procedures of the method used. Labs do not generally charge for quality control analyses. The only laboratory quality control that would affect field sampling procedures would be the addition of a surrogate(s) that is included in the methanol preservation solution for use on soil samples being analyzed for volatile organic contaminants, especially GRO and BTEX using AK101 or AK101AA. . Example checklists for data and for quality control review for Alaska Petroleum Hydrocarbon Methods AK 101, AK 102, and AK 103 are found in Tables 5A-5F. A list of common laboratory QC samples are in Section 9.2.1 of this chapter:

TABLE 5A. AK 101 Gasoline Range Organics- Sample Result Check Sheet

SAMPLE INFORMATION

Matrix	☐ Aqueous ☐ Soil ☐ Sediment ☐ Other:
Containers	☐ Satisfactory ☐ Broken ☐ Leaking:
Aqueous Preservation	☐ N/A ☐ pH<2 ☐ pH>2 Comment:
Temperature	☐ Received on Ice ☐ Received at 4°C ☐ Other:
Extraction Method	Water: Soil:

11 AK 101 ANALYTICAL RESULTS FOR FIELD SAMPLES

Field ID						
Lab ID						
Date Collected						
Date Received						
Date Extracted						
Date Analyzed						
Dilution Factor						
% Moisture (soil)						
Units						
RESULTS						
Total Gasoline Range Organics[1] Results						
Field Sample Surrogate % Recovery						
Field Sample Surrogate Acceptance Range	50-150%	50-150%	50-150%	50-150%	50-150%	50-150%

[1]Gasoline Range Organics data exclude concentrations of any surrogate(s) and/or internal standards eluting in that range

12 CERTIFICATION

1. Were all QA/QC procedures REQUIRED by the AK 101 Method followed? ☐Yes ☐No-Details attached
2. Were all performance/acceptance standards for the required QA/QC procedures achieved? ☐Yes ☐No-Details attached
3. Were any significant modifications made to the AK 101 method? ☐No ☐Yes-Details attached

SIGNATURE: _____

PRINTED NAME: _____ DATE: _____

Table 5B. AK 101 Gasoline Range Organics- Quality Assurance/Quality Control Sheet

SAMPLE INFORMATION

Matrix	☐ Aqueous ☐ Soil ☐ Sediment ☐ Other:
Extraction Method	Water: Soil:

13 AK 101 QUALITY CONTROL RESULTS FOR ANALYTICAL BATCH

Type	M. B.	LFB 1	LFB 2	CCS	CVS		
Field ID							
Lab ID							
Date Received							
Date Extracted							
Date Analyzed							
Dilution Factor							
% Moisture (soil)							
Units							
Method Blank Results							
Lab Fortified Blank (#1) % Recovery							
Lab Fortified Blank (#2) % Recovery							
LFB Acceptance Range		**60-120%**	**60-120%**				
LFB % RPD							
LFB % RPD Acceptance Limit			**20%**				
Continuing Calibration Sample Results							
CCS Acceptance Range				**75-125%**			
Curve Verification Sample (CVS) Results							
CVS Acceptance Range					**75-125%**		
Matrix Spike Result							
Matrix Spike Duplicate Result							
Surrogate % Recoveries for all QC							
Surrogate Acceptance Range	60-120%	60-120%	60-120%	60-120%	60-120%		

[1]Gasoline Range Organics data exclude concentrations of any surrogate(s) and/or internal standards eluting in that range

14 CERTIFICATION

1. Were all QA/QC procedures REQUIRED by the AK 101 Method followed? ☐Yes ☐No-Details attached
2. Were all performance/acceptance standards for the required QA/QC procedures achieved? ☐Yes ☐No-Details attached
3. Were any significant modifications made to the AK 101 method? ☐No ☐Yes-Details attached

SIGNATURE: _____

PRINTED NAME: _____ DATE: _____

Table 5C. AK 102 Diesel Range Organics- Sample Result Check Sheet

SAMPLE INFORMATION

Matrix	☐ Aqueous ☐ Soil ☐ Sediment ☐ Other:
Containers	☐ Satisfactory ☐ Broken ☐ Leaking:
Aqueous Preservation	☐ N/A ☐ pH<2 ☐ pH>2 Comment:
Temperature	☐ Received on Ice ☐ Received at 4°C ☐ Other:
Extraction Method	Water: Soil:

15 AK 102 ANALYTICAL RESULTS FOR FIELD SAMPLES

Field ID						
Lab ID						
Date Collected						
Date Received						
Date Extracted						
Date Analyzed						
Dilution Factor						
% Moisture (soil)						
Units						
RESULTS						
Total Diesel Range Organics[1] Results						
Field Sample Surrogate % Recovery						
Field Sample Surrogate Acceptance Range	50-150%	50-150%	50-150%	50-150%	50-150%	50-150%

16 CERTIFICATION

1. Were all QA/QC procedures REQUIRED by the AK 102 Method followed? ☐Yes ☐No-Details attached
2. Were all performance/acceptance standards for the required QA/QC procedures achieved? ☐Yes ☐No-Details attached
3. Were any significant modifications made to the AK 102 method? ☐No ☐Yes-Details attached

SIGNATURE: _____

PRINTED NAME: _____ DATE: _____

Table 5D. AK 102 Diesel Range Organics- Quality Assurance/Quality Control Check Sheet

SAMPLE INFORMATION

Matrix	☐ Aqueous ☐ Soil ☐ Sediment ☐ Other:
Extraction Method	Water: Soil:

17 AK 102 Quality Control RESULTS FOR ANALYTICAL BATCH

Type	M. B.	LFB 1	LFB 2	CCS	CVS		
Field ID							
Lab ID							
Date Received							
Date Extracted							
Date Analyzed							
Dilution Factor							
% Moisture (soil)							
Units							
Method Blank Results							
Lab Fortified Blank (#1) % Recovery							
Lab Fortified Blank (#2) % Recovery							
LFB Acceptance Range		**75-125%**	**75-125%**				
LFB % RPD							
LFB % RPD Acceptance Limit			**20%**				
Continuing Calibration Sample Results							
CCS Acceptance Range				**75-125%**			
Curve Verification Sample (CVS) Results							
CVS Acceptance Range					**75-125%**		
Surrogate % Recoveries for all QC							
Surrogate Acceptance Range	60-120%	60-120%	60-120%	60-120%	60-120%		

[1]Deisel Range Organics data exclude concentrations of any surrogate(s) and/or internal standards eluting in that range

18 CERTIFICATION

1. Were all QA/QC procedures REQUIRED by the AK 102 Method followed? ☐Yes ☐No-Details attached
2. Were all performance/acceptance standards for the required QA/QC procedures achieved? ☐Yes ☐No-Details attached
3. Were any significant modifications made to the AK 102 method? ☐No ☐Yes-Details attached

SIGNATURE: _____

PRINTED NAME: _____ DATE: _____

Table 5E. AK 103 Residual Range Organics- Sample Result Check Sheet

SAMPLE INFORMATION

Matrix	☐ Soil ☐ Sediment ☐ Other:
Containers	☐ Satisfactory ☐ Broken ☐ Leaking:
Temperature	☐ Received on Ice ☐ Received at 4°C ☐ Other:
Extraction Method	Soil:

19 AK 103 ANALYTICAL RESULTS FOR FIELD SAMPLES

Field ID						
Lab ID						
Date Collected						
Date Received						
Date Extracted						
Date Analyzed						
Dilution Factor						
% Moisture						
Units						
RESULTS						
Total Residual Range Organics[1] Results						
Field Sample Surrogate % Recovery						
Field Sample Surrogate Acceptance Range	50-150%	50-150%	50-150%	50-150%	50-150%	50-150%

20 CERTIFICATION

1. Were all QA/QC procedures REQUIRED by the AK 103 Method followed? ☐Yes ☐No-Details attached
2. Were all performance/acceptance standards for the required QA/QC procedures achieved? ☐Yes ☐No-Details attached
3. Were any significant modifications made to the AK 103 method? ☐No ☐Yes-Details attached

SIGNATURE: _____

PRINTED NAME: _____ DATE: _____

Table 5F. AK 103 Diesel Range Organics- Quality Control/Quality Assurance Check Sheet

SAMPLE INFORMATION

Matrix	☐Soil ☐ Sediment ☐ Other:
Extraction Method	Soil:

21 AK 103 Quality Control RESULTS FOR ANALYTICAL BATCH

Type	M. B.	LFB 1	LFB 2	CCS	CVS		
Field ID							
Lab ID							
Date Received							
Date Extracted							
Date Analyzed							
Dilution Factor							
% Moisture							
Units							
Method Blank Results							
Lab Fortified Blank (#1) % Recovery							
Lab Fortified Blank (#2) % Recovery							
LFB Acceptance Range		**60-120%**	**60-120%**				
LFB % RPD							
LFB % RPD Acceptance Limit			**20%**				
Continuing Calibration Sample Results							
CCS Acceptance Range				**75-125%**			
Curve Verification Sample (CVS) Results							
CVS Acceptance Range					**75-125%**		
Surrogate % Recoveries for all Quality Control							
Surrogate Acceptance Range	60-120%	60-120%	60-120%	60-120%	60-120%		

[1]Residual Range Organics data exclude concentrations of any surrogate(s) and/or internal standards eluting in that range

22 CERTIFICATION

1. Were all QA/QC procedures REQUIRED by the AK 103 Method followed? ☐Yes ☐No-Details attached
2. Were all performance/acceptance standards for the required QA/QC procedures achieved? ☐Yes ☐No-Details attached
3. Were any significant modifications made to the AK 103 method? ☐No ☐Yes-Details attached

SIGNATURE: _____

PRINTED NAME: _____ DATE: _____

9.2.1 List of Common Laboratory Quality Control Samples

Surrogates: The surrogate is analyzed and the recovery, expressed as a percentage, is intended to indicate the percent recovery of the contaminant. A surrogate is added to every sample that is being analyzed for organic compounds, including field quality control samples before sample preparation and analysis. In AK101, a methanol/surrogate solution is used in the field for preserving soil samples being analyzed for volatile organic compounds, especially, GRO and BTEX.

Retention time standard: A retention time standard is method specific and is used to verify the integration range. It also provides data for column performance. The elution pattern indicates expected boiling ranges for petroleum products that have boiling range production criteria.

Laboratory spike and laboratory spike duplicates samples: These samples are used to determine precision and accuracy of the analytical results through the percent recovery and relative percent difference. Quantities of stock solutions of the target contaminant(s) are added to laboratory matrix before it is extracted/digested and analyzed.

Matrix spike and matrix spike duplicate samples: These samples are used to assess and document the precision and bias of a method as a result of that specific sample matrix.

Reagent blank: The reagent blank is used to evaluate possible contamination of analytical process by target contaminants. No contaminant should be present in the reagent blank at a concentration greater than the method detection limit.

Bottle blanks: Bottle blanks may be used for diesel and gasoline organic analyses to determine if the bottles used are contaminant free.

Instrument blanks: The instrument blanks are used for diesel and gasoline analyses to determine if the instruments used are contaminant free.

SECTION 10. CORRECTIVE ACTIONS

Corrective actions are procedures and actions taken to correct unacceptable or unexpected deviations in sampling or analysis. An example is the re-analysis of one or more affected samples or the reporting of questionable data with a note of explanation on the situation. Ultimate responsibility for corrective actions rests with the qualified environmental professional. While appropriate corrective actions for out-of-control situations in the laboratory must be addressed by laboratory QA/QC documents, the owner or operator is responsible for ensuring that the qualified environmental professional shows that all corrective actions enable the data quality objectives to be met.

10.1 Handling Invalid Samples

If an invalid sample is taken, the following procedures must be followed:

(1) if the completeness objective for the project is met and observations and field screening do not indicate the invalid sample was collected at a location with higher than the average contamination levels at the site, an explanatory note of the deviation from this chapter must

accompany the report and no further corrective action for deviation is required; and

(2) if the completeness objective for samples at the site is not met or observations and field screening indicate the invalid sample was collected at a location with higher than the average contamination levels at the site, sample(s) must be recollected at the proper location on the site, properly analyzed and reported, and an explanatory note of the deviation from this chapter must accompany the data report.

10.2 Field Instrument Failure and Improper Use

If field instruments are being improperly used (or are not used), field data must be re-collected.

10.3 Failures in Data Processing, Management, or Analysis

Problems with data processing, management, or analysis is typically discovered during data reduction, validation, and reporting (see Section 8 of this chapter). If these problems occur, the owner or operator shall ensure that the QA officer or another appropriate person is notified. Upon review of the problem, the owner or operator shall ensure that the QA officer or other appropriate person

(1) initiates actions to correct the improper procedure; and

(2) adheres to procedures outlined for notifying the QA officer and project manager of potential problems with data quality.

10.4 Corrective Actions with Laboratory

Normally, any corrective actions necessary in a laboratory are handled internally by the approved laboratory through its approved QA/QC procedures on file with ADEC. The need for corrective action in the laboratory is identified by

(1) the laboratory's internal QC checks;

(2) the data review conducted by the qualified environmental professional (see Section 8.3 of this chapter); or

(3) the laboratory's performance audits.

APPENDIX A

Site Assessment and Release Investigation Summary Form

This document summarizes information from site assessments and release investigation reports that are required by Alaska's Underground Storage Tanks Regulations (18 AAC 78). It is intended to ensure minimum requirements are met when submitting full reports to ADEC. It cannot be substituted for comprehensive site assessment or release investigation reports. Site assessments (as defined in AS 46.03.450) are conducted to check for the presence or absence of petroleum contamination. If contamination of soil or groundwater is identified, then a release investigation is required. Site assessments and release investigations must be conducted by a qualified environmental professional (as defined in 18 AAC 78) and in accordance with Chapter two of the *Underground Storage Tanks Procedures Manual (UST Manual)*.

How to fill out this form
Type or print in ink the requested information and sign in ink the "signature" blocks on page 7. Please attach this form to the comprehensive site assessment or release investigation report (or include it in the report introduction) and submit it to the nearest ADEC field operations office (Juneau, Anchorage, Fairbanks, or Soldotna).

1. General Information

Purpose of Site assessment/ Release investigation: _____
(Closure, Change-in-service, Suspected or confirmed release, Compliance check, Other)

Owner of site: _____
Name of company/legal entity that owns the site Phone number

_____
Mailing address City, State, Zip code

Operator of site: _____
Name of company/legal entity that operates the site Phone number

_____
Mailing address of operator City, State, Zip code

Location of site: _____
Name of site (e.g. John Doe's Service Station) Phone number

_____
Physical address of site (be as specific as possible) City, State, Zip code

_____ _____
Legal description of site Section/township/range

_____ _____
Type of business at site Facility ID # / Tank ID number(s)

Financial Assistance

Applications filed (this site only) Site assessment/__ tightness test Tank cleanup__ Tank upgrade__ Tank closure__

Reports on file with ADEC: Tightness test__ Closure notice__ Other___ _____

2. System and tank status

Describe the status, size, and contents of the tanks that have been at the site:

Tank ID Number:	Tank No. ___	Tank No. ___	Tank No. ___	Tank No. ___	Tank No. ___
Tank status (check one) Currently in use	_____	_____	_____	_____	_____
Temporarily closure	_____	_____	_____	_____	_____
Closed/left in place	_____	_____	_____	_____	_____
Closed/removed	_____	_____	_____	_____	_____
Total capacity (gallons)	_____	_____	_____	_____	_____
Contents (diesel, etc.)	_____	_____	_____	_____	_____

3. Firm conducting site assessment and release investigation

_____
Name of firm Phone number

_____
Mailing address City, State, Zip code

_____
Qualified environmental professional Person(s) collecting samples

4. Site history

Based on the best available knowledge, please check the appropriate box below:

Y	N	
__	__	Was soil contamination observed or identified?
__	__	Was groundwater contamination observed or identified?
__	__	Did inventory control or prior tank repairs indicate a possible release?
__	__	Has a tank tightness test been performed on any USTs on the site?
__	__	Have any of the facility's USTs or piping ever failed a tightness test?
__	__	Have there been any previous site assessments performed at this site?
__	__	Do previous site assessments indicate any contamination has occurred?

If the answer to any of these questions is yes, please describe (or attach copy of report discussion). Give dates and circumstances, use continuation sheet if necessary:

5. Field screening analysis

Date(s) of field screening:_____ Temperature(s) during screening:_____
Estimated wind speeds:_____ Weather (clear, raining, etc.):_____
Type of field detection instrument used:_____
Brand:_____ Model: _____ Date calibrated: _____
Number of tests:_____ Range of results:_____

If an instrument wasn't used, what field detection method was used?_____
Number of tests:_____ Range of results:_____

6. Collection of soil samples

For site assessments done for USTs remaining in place

Check the appropriate boxes below (if not applicable, leave blank):

Y	N	
__	__	Were samples taken from borings (or test pits) within 5 feet of the UST?
__	__	Were samples collected from within 2 feet below the bottom of the UST?
__	__	Were dispensers connected to the UST system?
__	__	Were samples taken from borings (or test pits) adjacent to dispensers?
__	__	Were samples taken from borings (or test pits) adjacent to piping?

How many borings/pits were made?_____ How many samples were analyzed? _____

For site assessments done at excavation and removal of USTs:

Check the appropriate boxes below (if not applicable, leave blank):

Y	N	
__	__	Were any areas of obvious contamination identified or observed?
__	__	Were samples taken from areas of obvious contamination?
__	__	Were at least two discrete analytical samples taken from excavated pit area?
__	__	Was at least one sample taken from below each dispensing island's piping?
__	__	Was at least one sample taken from the piping trench?
__	__	Were the samples referenced above collected taken from native soil within two feet below the bottom of the tank pit or dispenser/piping trench?
__	__	If multiple tanks were removed, were at least three samples collected?
__	__	Were additional samples collected for each 250 square feet of excavated pit over 250 square feet?

Number of distinct points sampled:_____ Estimated excavation's surface area: _____

For all site assessments

Check the appropriate boxes below:

Y	N	
__	__	Were field duplicate samples collected and analyzed?
__	__	Were all samples kept at the appropriate temperature until analysis?
__	__	Were all samples extracted & analyzed within recommended holding times?
__	__	Did chain-of-custody/transfer logs accompany samples to laboratory?

7. Laboratory analysis of soil samples
(see Table 1 of *UST Procedures Manual*)

Identify the possible contaminants (gasoline, BTEX, diesel, etc.): _____

Please list the analytical methods used to detect these contaminants in the soil samples, the number of samples analyzed by each method, and the range of results for each method:

Possible product	**Analytical method**	**Number of samples**	**Range of results**	**Location(s) of sample point(s) w/highest level of contamination**
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

8. Groundwater investigation
Check the appropriate boxes below:

Y	N	
__	__	Was groundwater encountered during the excavation or drilling work?
__	__	Were borings drilled/pits dug at least five feet below the USTs bottom?
__	__	Is groundwater or seasonal high water table known or suspected to exist within five feet of the bottom of the USTs?

Y	N	
__	__	Were samples taken from borings drilled/test pits dug to this water level?
__	__	Were all these samples analyzed within recommended holding times?

How many groundwater/saturated-soil samples were collected & analyzed? _____

How many of these samples were taken from the top 6" of water table? _____

How many field QC samples were analyzed? _____ _____ _____
Trip blanks Duplicates Decon blanks

9. Laboratory analysis of water samples
(see Table 1 of *UST Procedures Manual*)

Identify the possible contaminants at the site: _____

Identify the analytical methods used to detect these contaminants in the water samples, the number of samples analyzed by each method, and the range of results for each method:

Analytical method	**Number of samples**	**Range of results (ppm)**	**Location(s) of sample point with highest level of contamination**
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

10. Disposal of material

Check the appropriate boxes below (if not applicable, leave blank):

Y	N	
__	__	Were tanks cleaned in accordance with API 2015 (Cleaning Petroleum Storage Tanks)?
__	__	Were the tanks and piping removed and disposed in accordance with API 1604 (Removal and disposal of used petroleum Storage tanks)?

Where were the tanks and piping disposed?_____
_____

Where was the tank sludge and rinsewater disposed?_____
_____

11. Stockpiles

Check the appropriate boxes below:

Y	N	
__	__	Is any soil stockpiled at the site?
__	__	Are soils stockpiled in accordance with 18 AAC 78.274?

12. Release investigation

Check the appropriate box below:

Y	N	
__	__	Was any petroleum contamination identified during site assessment? (Answer "yes" if any evidence a release occurred; if no, proceed to item 13)

If contamination was found, what was matrix score for site? _____
(Attach completed matrix score sheet to this form)

When did release occur?_____ When was release confirmed? _____
(Date & time) (Date & time)

When was ADEC notified? _____ List ADEC staff notified:_____
(Date & time) (Name)

What is status of UST that prompted the investigation?

____	_____	_____	_____
In use	Out-of-use, product still in system	Out-of-use, system empty	Permanently closed

Briefly describe (or attach copy of report discussion) the steps taken to prevent further migration of the release and steps taken to monitor and mitigate fire and safety hazards:

_____

_____

_____

13. Site sketch

Sketch the site in the space below. Alternatively, attach a site map to the back of the form. The sketch (or accompanying narrative) should include the following information:

locations of all USTs, piping, and dispensers
distances from tanks to nearby structures
property line locations
location and dimensions of excavation(s)
type of backfill used to surround system
locations of any known historical releases
locations of any observed contamination
location of any boreholes and test pits
soil types
field screening locations and readings
sampling locations, depths, & sample ID numbers
water wells and monitoring wells (if present)
depth to groundwater/seasonal high location
locations of any stockpiled soils
north arrow
bar scale (specify feet or meters)
current land use; human and environmental receptors

For release investigations, in addition to the above information, show the groundwater gradient; surface drainages (including potential hydraulic connections with groundwater) and utility trenches.

14. Quality assurance

Check the appropriate boxes below:

Y	N	
__	__	Were there deviations from Chapter 2 of the *UST Procedures Manual*? (Note that any deviations must be documented in a section of the comprehensive report)
__	__	Is a field quality control summary included in the reports?
__	__	Is a laboratory QC summary included in the report for all samples used to verify cleanup standards have been met?

15. Certification

The following certification is to be signed by the Qualified Environmental Professional or Quality Assurance Officer:

I certify that except as specifically noted in this report, all statements and data appearing in this report are in conformance with the provisions of Chapter 2 of the *UST Procedures Manual.*

_____ _____

(Print name) (Title)

_____ _____

(Signature) (Date)

The following certification is to be signed by the UST owner/operator (or designated representative):

I certify that I have personally examined and am familiar with the information in this and all attached documents and based on my inquiry of the individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete.

_____

(Print name)

_____

(Specify if owner, operator, representative)

_____ _____

(Signature) (Date)

_____ _____

(Street Address) (City, State, Zip)

16. Attachments

Please check the boxes showing any comprehensive reports attached to this summary:

____ Site Assessment Report (include if no release investigation is needed)

____ Release Investigation Report (include if release investigation is needed)

APPENDIX B

Laboratory Data Report Check Sheet

The following items are to be kept on file at the lab for ten years after analysis.

Reviewer _____ Date _____

Project _____

Laboratory _____

LAB INFORMATION

- ☐ Laboratory name
- ☐ Address
- ☐ Fax number
- ☐ UST Lab ID Number
- ☐ Telephone number
- ☐ Email

METHOD AND SAMPLE INFORMATION

- ☐ Analyte of interest, or target analyte
- ☐ Extraction method #
- ☐ Name
- ☐ Extraction solvent used
- ☐ Site or project name
- ☐ Date sampled
- ☐ Date extracted
- ☐ Ambient container temperature upon receipt of sample
- ☐ Sample refrigerated
- ☐ Sample transfer log/release/chain-of-custody form
- ☐ Lab file ID number
- ☐ Type of matrix
- ☐ Field sample number
- ☐ Lab sample number
- ☐ Sample collection point
- ☐ Date received
- ☐ Date analyzed
- ☐ Time/date temperature measured
- ☐ Temperature
- ☐ Date/time

RESULTS

- ☐ Concentration of analyte (mg/kg dry or mg/L)
- ☐ % solids analysis or explanation
- ☐ Dilution factor
- ☐ Volume of sample purged
- ☐ Case narrative summary

QC INFORMATION

- ☐ QA Officer Signature
- ☐ Date signed
- ☐ Method detection limit or method reporting limit indicated
- ☐ Calculation examples/explanations
- ☐ Identification of flags or qualifiers
- ☐ All corrections and strikeouts initialed and dated
- ☐ Precision and accuracy value for each sample set
- ☐ Report date

APPENDIX B - LABORATORY DATA REPORT CHECK SHEET (Cont.)

FINAL REPORT

- ☐ Analyst's name on all report pages
- ☐ Date prepared
- ☐ Analyst's signature/initials on all chromatograms
- ☐ Report securely bound
- ☐ With sequentially numbered pages

CHROMATOGRAMS & INTEGRATIONS

- ☐ Original data package (with analyst's initials)
- ☐ Sample queue
- ☐ Chromatograms included
  - ☐ clearly labeled
  - ☐ baseline-baseline integrated
- ☐ Integration report included (clearly labeled)
- ☐ Integration range clearly indicated
- ☐ Date/time on all chromatograms

CALIBRATION INFORMATION

- ☐ Calibration report (with analyst's initials)
- ☐ Date/time of initial calibration
- ☐ Concentration range clearly indicated
- ☐ Composition of calibration standard(s)
- ☐ Lab Control Standard analyzed, date/time
- ☐ Continuing Calibration Standard analyzed, date/time

SURROGATE USED

- ☐ Surrogate properly identified
- ☐ % recovery for each sample
- ☐ Acceptable range indicated
- ☐ Outliers explained

APPENDIX B - LABORATORY DATA REPORT CHECK SHEET (Cont.)

COLUMN PERFORMANCE

- ☐ Alkane/window retention time standard analyzed
- ☐ Components properly identified
- ☐ Date determined
- ☐ Analyst's initials

SPIKES

- ☐ Spike/spike duplicate (if analyzed)
- ☐ Recoveries
- ☐ Relative % difference
- ☐ Acceptable range clearly indicated
- ☐ Narrative

BLANKS

- ☐ Method blank

OPTIONAL

- ☐ Reagent blank
- ☐ Bottle blank
- ☐ Reference (library) sample included
- ☐ Pattern match/narrative
- ☐ Summary

APPENDIX C

Alaska Series Laboratory Methods for the Analysis of Gasoline Range Organics (AK101), Diesel Range Organics (AK102), and Residual Range Organics (AK103)
Forward for AK Methods 101, 102, and 103

The Alaska Department of Environmental Conservation (ADEC) has published these laboratory methods to provide ADEC-approved laboratory test methods and related information for laboratory analysts, data users, and other interested parties. The test methods may be used, without permission, for laboratory testing to provide measurements relative to regulations in ADEC programs. **Except where specified in 18 AAC 60, 18 AAC 75, or 18 AAC 78**, the use of these test methods is not mandatory.

These test methods have been written to provide comprehensive guidance for analysts attempting to analyze samples. However, ADEC does not intend for users to follow all details of a method in a prescriptive, rote fashion. Rather, **except where specifically indicated by the words "shall," "must," or "required,"** analysts have the flexibility to modify method procedures, parameters, equipment, reagents, etc. for all method steps, if the changes do not adversely affect the method performance needed to achieve the data quality needs of the study being conducted. Examples of the types of flexibility allowed include changes in chromatographic conditions, columns, traps, sample extraction conditions, glassware, and sample size.

The flexibility is intended to provide laboratories a way to improve test methods (for example, reduce the generation of laboratory wastes, use existing equipment, reduce costs) without having to undergo elaborate studies and a time-consuming approval process. In exercising this flexibility, laboratories must be able to demonstrate and document that the changes implemented can produce results that are consistent with the data quality needs of the intended application, based on the results of initial and ongoing quality control activities.

Chapter One of EPA's *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, describes a variety of quality control activities that may be used to evaluate the appropriateness of any method modification and of the sample results. Additional quality control activities are described in each method.

The test methods provide information relative to the expected performance (accuracy, precision and sensitivity) of the method when applied by a well-operated laboratory. These performance data should be used both to assist in the selection of a method for a given application and to evaluate whether a modification is appropriate.

In summary, the test methods provide comprehensive guidance which may be used by laboratories, individual analysts, and the regulated community. The results from quality control sample analyses are used to evaluate the quality of sample results relative to the intended use of the data.

Method AK101

For the Determination of Gasoline Range Organics
Version 04/08/02

1. Scope and Application

1.1 Analytes

1.1.1 This method is designed to measure the concentration of Gasoline Range Organics (GRO) in water and soil. This corresponds to an alkane range from the peak start of n-hexane (C_6) to the peak start of n-decane (C_{10}), and to a boiling point range between approximately 60°C and 170°C (see example of chromatogram in Figure 1 of this method.

1.1.2 Components with boiling points greater than or equal to C_{10} present in products such as diesel or fuel oil are detectable under the conditions of the method.

1.1.3. With the optional photo ionization detector (PID), this method can be extended for specific determination of volatile aromatics (BTEX) as specified in EPA Method SW-846 8021B. **Please be aware that any reference to 8021B is in regard to apparatus and not sample preparation. All AK101 samples must be preserved with methanol.**

1.2 Quantitation Limits

The Practical Quantitation Limit (PQL) of this method for GRO must not exceed 20 mg/kg GRO as gasoline for soils and 100 µg/L GRO as gasoline for water.

1.3 Dynamic Range

Dilutions should be performed as necessary to put the chromatographic envelope within the linear range of the method. In general, the approximate range is 50 to 2,000 µg/L of gasoline.

1.4 Experience

This method is based on a purge-and-trap, Gas Chromatography (GC) procedure. This method must be used by, or under supervision of, analysts experienced in the use of purge-and-trap systems and gas chromatographs as a quantitative tool.

2. Method Summary

2.1 This method provides gas chromatographic conditions for the detection of volatile petroleum fractions such as gasoline. Other nonpetroleum compounds with similar characteristics and boiling points may also be detected with this method. The gas chromatograph is temperature programmed to facilitate separation of organic compounds. A flame ionization detector (FID), or PID/FID in series, provides detection. Quantitation must be performed by comparing the total chromatographic area between and including C_6 (n-hexane) and C_9 (n-nonane), to the peak start time of C_{10} (n-decane), including resolved and unresolved components, based on FID response compared to a blended commercial gasoline standard (Section 3.2 of this method) and using forced baseline-baseline integration. (See Table 1 of this method for suggestions regarding purge-and-trap operating parameters.)

2.2 Water samples must be analyzed directly for GRO by purge-and-trap extraction and gas chromatography. Soil or waste samples are dispersed in methanol to dissolve and preserve the volatile organic constituents (see Table 2 of this method). A portion of the methanol solution is injected into water, and then analyzed in a manner similar to water analysis. Conversely, methanol extracts may be injected directly into the GC/PID/FID if all quality control criteria of the methods are met.

2.3 Special field sampling techniques are required to minimize the loss of volatile organic compounds from soil. Conventional sampling and sample handling techniques are not acceptable.

2.4 Benzene, toluene, ethylbenzene and total xylene isomers (BTEX) may be determined simultaneously with GRO if the gas chromatograph is outfitted with the optional PID detector, and all requirements of EPA SW-846 Method 8021B are met.

2.5 This version of the method was developed by Mary Jane F. Pilgrim, Ph.D. It is based, in part, on: U.S. EPA SW-846 [1] methods 5030, 8000, 8021B, 8015; a single laboratory method evaluation study conducted by the American Petroleum Institute (API) [2]; work by the EPA Total Petroleum Hydrocarbons Methods Committee [3]; and work by the Alaska Department of Environmental Conservation, State Chemistry Laboratory, with support from the Contaminated Sites Program.

3. Definitions

3.1 Gasoline Range Organics (GRO): All chromatographic peaks, both resolved and unresolved, eluting between the peak start time for C_6 (n-hexane) and the peak start time for C_{10} (n-decane). Quantitation is based on a direct comparison of the baseline - baseline integrated area within this range to the total area of the calibration standard over the same (C_6 - C_{10}) range, using FID response. Surrogate peak areas shall be determined by valley to valley integration.

3.2 Gasoline Calibration Standard (GCS): An equal-weight mixture of regular, plus, and premium grades of commercial gasoline, mixed and diluted to appropriate concentrations, used to prepare a standard curve.

3.3 Calibration Verification Standard (CVS): A gasoline quality control standard (Certified, or equivalent) prepared as in Section 3.2 of this method but with product from a source other than that used to prepare the GCS. This standard serves as a quality control check to verify the accuracy of calibration.

3.4 Continuing Calibration Standard (CCS): A mid-range working standard diluted from the GCS, used to verify that the analytical system is operating in a manner comparable to that at the time of calibration.

3.5 Surrogate: The recommended surrogate is either bromofluorobenzene or α,α,α-trifluorotoluene. Other compounds may be used as a surrogate if they are non-polar, purgeable from water and methanol, and do not co-elute with any significant component of the GCS and elute prior to the start of C_{11}. Surrogates may be added in the field or the laboratory or both.

3.6 Surrogate Blank: A laboratory or field blank sample spiked with the surrogate used in the sample batch. The surrogate recovery is used to evaluate method control (see Section 7.3 of this method).

3.7 Laboratory Fortified Blank (LFB): A method blank sample spiked with a commercial gasoline or blend of gasoline. The spike recovery is used to evaluate method control. The CVS may be used as the Laboratory Fortified Blank.

3.8 Retention Time Window Standard: A normal alkane standard containing n-hexane and n-decane (C_6 and C_{10}) which is analyzed once per 24 hour day or with each batch of samples, whichever is less frequent, not to exceed 20 samples per batch. This standard is used to establish the retention time window for quantitation of GRO. The compounds of BTEX can be included if all quality control criteria are met (see Section 10 of this method).

3.9 Method Detection Limit (MDL): The minimum concentration of a compound that can be measured and reported with 99 percent confidence that the value is greater than zero, determined from analysis of a sample in a given matrix containing the analyte. (See 40 C.F.R. 136, Appendix B, for method of determining method detection limit.) Each laboratory must demonstrate and periodically update method detection limits for each analyte of interest. MDL's must be updated when a significant change in instrument, method, or personnel occurs.

3.10 Practical Quantitation Limit (PQL): Five times the MDL.

3.11 Instrument blank: Reagent water known to be free of purgeable compounds within the integration window. Analyzed prior to the start of an analytical batch to demonstrate the analytical system is free of contamination.

3.12 Other terms are as defined in SW-846 [1].

4. Interferences

4.1 High levels of heavier petroleum products such as diesel or heating fuel may contain some volatile components producing a response within the retention time range for GRO. Other organic compounds, including chlorinated solvents, ketones, and ethers are also detectable by this method. As defined in the method, the GRO results include these compounds.

4.2 Samples contaminated with a single compound which is detectable using this method (e.g., some solvents,) and which are quantitated against the GCS, may result in a value which is biased for that compound. This is caused by the difference in response factors for the GCS and various solvents. An alternative calibration, detection or quantitation procedure may be appropriate if the identity and quantity of the compound are specific project concerns.

4.3 Samples can become contaminated by diffusion of volatile organics during shipment and storage. A trip blank prepared from reagent water (for water samples) or methanol (for soil and sediment samples) and carried through sampling and subsequent storage and handling is highly recommended to serve as a check for such contamination.

4.4 Contamination by carryover can occur when high-level and low-level samples are sequentially analyzed. To reduce carryover, the sample syringe and purging device should be rinsed between samples with reagent water and methanol. If an unusually concentrated sample is encountered, analysis of a solvent blank or reagent water to check for contamination should follow it. For volatile samples containing high concentrations of water-soluble materials, suspended solids, high boiling compounds, or organohalides, it may be necessary to wash the syringe or purging device with a detergent solution, rinse with distilled water and methanol, and then dry in a 105° C oven between analyses. The

trap and other parts of the system are also subject to contamination. Therefore, frequent bake-out and purge of the entire system may be necessary. A screening of all samples prior to analysis is recommended to protect analytical instrumentation (see Section 9.6.1 of this method).

4.5 High moisture content in soil samples may cause moisture dilution resulting in results biased low. Moisture dilution is dilution of methanol preservative by moisture contained in the sample.

5. Safety Issues

5.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined. However, each chemical compound should be treated as a potential health hazard. Exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material safety data sheets should also be made available to all personnel involved in chemical analyses. Additional references to laboratory safety should be made available and identified for the information of the analyst. Some data (i.e., on methanol) is available from ADEC.

6. Apparatus and Materials

Unless otherwise indicated, apparatus and materials are representative, not required. Except for soil sample preservation, refer to EPA Methods 5030, 602 and 8021B for remaining equipment and reagent. For soil sample preservation, see Section 8.2 of this method.

6.1 Glassware

6.1.1 40-mL glass vials with Teflon-lined septa and screw caps (a.k.a., VOA or VOC vials).

6.1.2 4-oz. amber glass wide mouth jars with Teflon-lined septa that are fused to the screw caps.

6.1.3 Volumetric flasks, class A: 10-mL, 50-mL, 100-mL, 500-mL, and 1000-mL with ground glass stoppers.

6.1.4 Disposable pipettes: Pasteur.

6.2 Syringes

6.2.1 5-mL Luerlock glass syringe and 5-mL gas-tight syringe with shutoff valve.

6.2.2 For purging large sample volumes for low detection limit analysis, 25- or 50-mL syringes may be used. Remember to adjust other volumes as necessary throughout the method.

6.2.3 Micro-syringes: 1-, 5-, 10-, 25-, 100-, 250-, 500-, and 1000-µL.

6.3 Analytical balance, capable of accurately weighing to the nearest 0.0001 g for preparation of standards and percent moisture determinations and a top-loading balance capable of weighing to the nearest 0.01 g for samples.

6.4 Stainless steel spatula

6.5 Gas Chromatography

6.5.1 Gas Chromatograph: Analytical system complete with gas chromatograph suitable for purge-and-trap sample introduction and all required accessories, including detectors (FID required, additional PID optional), column supplies, gases and syringes. A data system capable of determining peak areas using a forced baseline and baseline projection is required. A data system capable of storing and reintegrating chromatographic data is recommended. Disclaimer: Suggestions for columns and traps, necessary for the proper completion of this procedure, are the recommendations at the time of the published revision. As new advancements are developed it is acceptable to replace dated technology as long as it can be demonstrated that the quality control criteria of the method is intact.

6.5.2 Columns:

6.5.2.1 Column 1: HP5MS. 30-m x 0.32 mm ID. 100 micron film thickness or equivalent.

6.5.2.2 Capillary columns may be essential to achieve necessary resolution. The column must resolve C_6 from the methanol solvent front in a mid-range LCS standard and, if BTEX is to be done simultaneously, must resolve ethylbenzene from m/p-xylene.

6.5.2.3 The column must be capable of separating typical gasoline components from the surrogate and (optional) internal standard.

6.5.3 Purge-and trap device: The purge-and-trap device consists of three separate items: the sample purger (sparging device), the trap, and the desorber (furnace). Several complete assemblies are commercially available. (See Table 1 of this method for summary of operating parameters.)

6.5.3.1 Purging chamber: The recommended purging chamber is designed to accept 5-mL samples with a water column at least 3-cm deep. The gaseous headspace between the water column and the trap should have a

total volume of less than or equal to 15 mL. In any case, the purge chamber must be configured so that the quality assurance requirements specified in Section 10 of this method are met. A 25-mL chamber may be necessary to meet project specific detection limit requirements.

6.5.3.2 Trap: The trap must be capable of retaining GCS components at the highest concentration of the calibration curve, and concomitantly meet the quality assurance requirements specified in Section 10 of this method. Before initial use, the trap should be conditioned as specified by the manufacturer. Vent the trap effluent to the hood, not to the analytical column. Before daily use, the trap should be conditioned, according to manufacturer's specifications, with back flushing. The trap may be vented to the analytical column during daily conditioning; however, the column should be run through the temperature program before analysis of samples to assure that any contamination from trap conditioning has been removed.

Suggested traps are the "J" trap or BTEX trap and should be conditioned and used according to manufacturer's specifications.

6.5.3.3 - Desorber (Furnace): The desorber should be capable of rapidly heating the trap to the required temperature for desorption. The trap should not be heated higher than the manufacturer specified tolerances.

6.5.4 The purge-and-trap device may be assembled as a separate unit or may be coupled to a gas chromatograph, as long as complete transfer of the sample is assured.

7. Reagents and Standards

7.1 Reagent Water: Carbon-filtered, purged water which has been shown to be free from purgeable compounds (this has also been called organic-free water). Nitrogen or helium may serve as purge gas.

7.2 Methanol: Pesticide grade or equivalent. Store away from other solvents. At a minimum, the methanol must not show GRO contamination above the PQL.

7.3 Stock Standard Solutions - Prepare the following stock standards. Unless otherwise noted, all are prepared using the methanol listed in 7.2 as solvent. Standard preparation should follow guidelines in SW-846 [1]. All standards prepared by the laboratory must be stored without headspace at -10° to -20°C and protected from light. Standards must be replaced within 6 months of preparation. Standards should be checked regularly to assure their integrity. Standards that are purchased pre-made from commercial suppliers may be kept for the life, and under conditions, specified by the manufacturer if different than described in this paragraph.

7.3.1 Internal Standard: An internal standard (1-chloro-4-fluorobenzene) is

recommended for 8021B quantitation on the PID. Due to potential interferences, the internal standard is not recommended for GRO (FID) quantitation.

7.3.2 Recommended Surrogates: 50 µg/mL of bromofluorobenzene and / or α,α,α-trifluorotoluene. Add 5.0 µL of this surrogate directly into the 5-mL syringe with every sample and standard analyzed. Surrogate is spiked into soil samples during the extraction step (see Section 8.2.1 of this method). A second surrogate may be used in addition to, but not in place of, the surrogate sent to the field (Section 8.2.1). The use of alternate surrogates is optional. Surrogate compounds must be non-polar, purgeable from water, elute prior to the start of C_{11} and must not co-elute with any significant component of gasoline. Surrogated methanol is prepared at a ratio of 2.5 mL of methanol to 0.5 mL of surrogate spiking solution at 50 µg/mL.

7.3.3 Retention Time Window Standard: This mixture of n-hexane and n-decane serves as a retention time window defining mix for GRO. The concentration of the individual components should not be less than 500 µg/mL and not more than 1000 µg/mL. Additional analytes may be added to this mix if 8021B is to be done concomitantly.

7.3.4 Calibration Standards: A mixture of equal weights of regular, plus, and premium grades of unleaded gasoline serves as the Gasoline Calibration Standard. Gasoline standards must be certified as non-oxygenate gasoline or the gasoline concentration must be adjusted to reflect the contribution from oxygenates. No fewer than 3 concentrations of the GCS are diluted directly into a 5-mL Luerlock syringe (linear range approximately 50 to 2,000 µg/L) at the time of calibration. BTEX calibration should meet the criteria specified in EPA SW-846 Method 8021B for waters and soils [1]. Other than one standard concentration near the practical quantitation limit, the expected range of concentrations found in the field samples should define the working range of the GC (see Section 9.3.2 of this method).

7.3.5 Stock Standard for Calibration Verification: From a blend of oxygenate free commercial gasoline other than those used to prepare the GCS, make an equal weight mixture as described in Section 7.3.4 of this method. Prepare a dilution of 500 ug/mL in methanol.

Note: When verifying the BTEX calibration curve, the criteria in the appropriate EPA method should be met [1, 12].

8. Sample Collection, Preservation, Handling, and Holding Times

8.1 Aqueous Samples:

8.1.1 Aqueous samples should be collected without agitation and without headspace in contaminant-free, amber glass 40-mL vials with Teflon-lined septa in the caps. A sufficient number of samples should be collected to provide for quality control criteria and for back-up in the event of breakage. If amber glass vials are not available, clear glass may be substituted if the samples are protected from light. The Teflon layer must contact the sample (zero headspace). Sample vials should contain 200 µL of 50% hydrochloric acid (HCl) as a preservation for volatile analytes. Refrigerated samples (4 ± 2° C) must be analyzed within 14 days of collection.

8.1.2 A trip blank (contaminant-free amber glass 40-mL vial with Teflon-lined septum, filled to zero headspace with purged, organic free water preserved with the same acid as the samples, if possible) must accompany each shipping container and should be stored and analyzed with the field samples. Trip blank analysis is not required if all samples in a shipping container are less than the project specific cleanup level.

8.2 Soils and Sediments: Soil and sediment samples require special procedures to minimize the loss of volatile organic compounds during transit from the field to laboratory. **Please note that this sample preservation is different from SW-846 Method 8021B. The use of sodium bisulfate as a preservative is not acceptable.**

8.2.1 Soil or sediment samples must be collected into appropriately sized containers and submerged in surrogated methanol.

8.2.2 Solid samples must be collected with minimum disturbance into tared jars with a Teflon-lined septum fused to the lid. Jars should be 4-oz or larger, if appropriate. 25-mL aliquots of methanol (includes 1.2 mL of a surrogate solution at 50 µg/mL) should be carefully added to the undisturbed soil until the sample is submerged.

8.2.3 It is extremely important that the weight of the jar, the weight of the methanol/surrogate solution, and the weight of the sample collected be known. These must either be measured directly, or sufficient information documented so that these weights can be calculated.

8.2.4 The ratio of soil to methanol used to calculate the MDL and PQL offered in this method was 1:1 (w:w). However, absorbent, organic soils such as muskeg and tundra will require a higher methanol-to-sample ratio, while beach sand may tolerate a lower ratio.

8.2.5 Soil for volatiles analysis can be collected using any coring device that minimizes soil disturbance. Any scraping, stirring, or similar activity will result in a loss of volatiles during sampling. A sufficient number of samples should be collected to provide for backup in case of breakage.

8.2.6 Although it is not necessary to refrigerate all methanol preserved samples at 4° ± 2° C after collection and until analysis is complete, collected samples must be kept below 25° C.

8.2.7 A second surrogate, added to the methanol and soil mixture after sample collection, may be used in addition to, but not in place of, the surrogate with which the field methanol preservative was prepared.

8.2.8 A reagent methanol trip blank must be prepared in the same manner as the sample vials, and must contain surrogated methanol. One trip blank must be included with each shipping container and must be stored and analyzed with the field samples. Trip blank analysis is not required if all samples in a shipping container are less than the project specific cleanup level.

8.2.9 Field blanks may be added to the sampling protocol and are prepared in the field by addition of surrogated methanol to the prepared container, as required by the qualified environmental professional or the Project Manager.

8.2.10 A sample of the same soil to be analyzed for GRO should be collected into a moisture-proof container for per cent moisture determination. This sample should be processed as soon as possible upon arrival at the laboratory to assure that the resulting moisture determination is representative of the preserved sample as surveyed.

8.2.11 Trip blanks, field blanks, method blanks, etc. should be prepared from the same batch of solvent, reagents and vials as are used for sample preservation.

8.3 Twenty-eight days is the maximum holding time for soil and sediment samples collected under this section.

8.4 Because the jars are pre-weighed, it is extremely important that the sampler put evidence tape on the kit ONLY, or the bubble bags in which the sample bottles are shipped, and not on the individual bottles. Removal of evidence tape is extremely difficult and the additional weight biases final results. Also, the glue on the evidence tape can contribute to the volatiles concentration in the sample (per Rocky Mountain Analytical, direct communication).

8.5 Trip blanks, field blanks, and bottle blanks should be prepared as appropriate to meet the quality assurance goals of the project plan.

8.6 Performance Evaluation (PE) Samples must be obtained from a supplier approved by The NELAC Institute (TNI) or a supplier approved to ISO 17043 standards.

9. Procedure

9.1 Volatile compounds are introduced into the gas chromatograph by purge-and-trap (see exception, Section 2.2 of this method). Purge gas should be set at a flow rate of 25 - 40 mL/min. and purge time at 12 min., or conditions necessary to optimize the resulting chromatography.

9.2 Waters:

9.2.1 Purge-and-trap may be used directly on most water samples.

9.2.2 Water samples high in dispersed sediments (non-settling or slow settling solids) must NOT be filtered before analysis, as this results in loss of volatiles. Centrifugation also forces the gases out of the water matrix. In most cases, a muddy water sample can be left undisturbed until the solids settle out. An aliquot of the sample can then be taken with a 5-mL gas tight syringe, being careful not to disturb the sediment layer. Introduction of sediment into the purge device can result in occlusion of the frit, leading to incomplete purging of the sample and low-biased results. In any case, sample preparation should be noted, and an approximate volume given for the solids, if present.

9.3 Soils and Sediments:

9.3.1 Soils and solids are methanol extracted. An aliquot of the extract is added to reagent water and analyzed as in Section 9.10 of this method.

9.3.2 For best retention of volatile compounds, samples should be collected into tared, sample jars containing the methanol-surrogate solution (see Section 8.2 of this method).

9.3.3 The entire volume of soil must be submerged in the methanol-surrogate solution.

9.3.4 Weigh the sample jar upon receipt and record the total filled weight. Swirl the jar gently for 2 minutes to be sure that the soil sample is dispersed into the methanol, and allow the sediment to settle. It is recommended that the meniscus of the methanol be marked and dated on the outside of the jar.

9.3.5 Best results are obtained by allowing the sample volatiles to equilibrate with the methanol for at least 48 hours before continuing with the analysis. However, this is not always possible. In any case, note the time difference between when the

methanol was delivered into the soil sample and when analysis was initiated.

9.4 Soils and Sediments Collected without Methanol Preservation:

9.4.1 When solids are collected by the sampling techniques described in SW-846 [1], volatile results are biased low. Therefore, data from these samples (collected without methanol preservative) must be reported as "greater than or equal to" the calculated mg/kg GRO as gasoline and may not be accepted as valid by state project managers.

9.4.2 To prepare extracts from these types of collection containers, gently mix the contents of the sample container with a narrow metal spatula. Do not discard any supernatant liquids, as the entire contents of the sample container must be represented.

9.4.3 For sediment/soil and waste that are insoluble in methanol, weigh 10 g (wet weight) of sample into a tared 20-mL vial, using a top loading balance. Note and record the actual weight to 0.1 g.

9.4.4 Quickly add 9.5 mL of methanol and 0.5 mL of the 50 ug/mL surrogate spiking solution to the vial (or, after adding spiking solution, fill to the line on the volumetric flask), cap and swirl (do not shake) for 2 minutes.

9.4.5 Allow sediment to settle. The alternate sample preparation procedure must be noted on the data transmittal.

Note: To avoid loss of volatile organics or cross contamination, these steps must be performed rapidly and without interruption, in a laboratory free from gasoline or solvent fumes.

9.5 Methanol Soluble Solids:

9.5.1 For waste that is soluble in methanol weigh 1 g (wet weight), to the nearest 0.01 g into a tared 10-mL volumetric flask.

9.5.2 Quickly add 9.5 mL of methanol and 0.5 mL of the 50 µg/mL surrogate spiking solution to the vial (or, after adding spiking solution, fill to the line on the volumetric flask), cap and swirl for 2 minutes, to disburse the waste into the methanol.

9.5.3 Allow sediment to settle, pipette an aliquot to an amber glass vial for storage at 4° ± 2°C (zero headspace).

9.6 Sample Screening:

9.6.1 It is highly recommended that all samples be screened prior to analysis, as these samples may contain enough petroleum to overload the column and/or detector(s). This screening step may be analysis of a solid sample's methanol extract (diluted) using AK101, the headspace method (SW-846 Method 3810 [1]) or the hexadecane extraction and screening method (SW-846 Method 3820 [1]).

9.7 Gas Chromatography Conditions (recommended)

9.7.1 Column 1: Set helium column pressure to 20#. Set column temperature to 30° C for 1 min., then ramp at a rate of 5° C/min. to 100° C, then 8° C/min. to 240° C and hold for 7.5 min. Conditions may be altered to improve the resolution of GRO. H_2 may be used as carrier gas, N_2 as purge gas. Conditions may be altered to accommodate the optional gases.

9.7.2 Other columns: Set GC conditions to meet the criteria in Section 6.5.2.2.

9.8 Calibration:

9.8.1 The GC system should be set up as in Section 6.5. This should be performed prior to calibration or to final preparation of the samples or sample extracts for analysis.

9.8.2 The GRO calibration curve must be represented by no fewer than 3 concentrations of GCS (a 5 point calibration curve is recommended). Prepare final solutions of GCS and surrogate directly in a 5-mL glass Luerlock syringe containing reagent water. Using a microsyringe, add the aliquot of calibration standard directly to the reagent water in the glass syringe (refer to Section 9.10.7 of this method) by inserting the needle through the syringe opening. When discharging the contents of the microsyringe, be sure that the tip of the needle is well beneath the surface of the reagent water to prevent escape of calibration standard components. Similarly, add the SCS. The concentration of the surrogate can increase with increasing GCS concentration, or remain at a fixed value for all calibration standards and samples. Inject the prepared dilution(s) into the purge vessel(s) through the two-way valve, and proceed with calibration.

9.8.3 Choose GCS concentrations to cover the GRO range expected in the samples or the linear range of the instrument, whichever is less. One of the concentrations must be near the practical quantitation limit. Due to potential carry over, it is recommended that not more than 10 µg of gasoline in 5 mL of water (2 mg/L) be purged.

9.8.4 Tabulate the area response of the gasoline against mass injected. The ratio of the amount injected to the response, the response factor (RF), can be calculated for the standard at each concentration. If the percent relative standard deviation (%RSD) is less than 25% over the working range, linearity through the origin can

be assumed, and the average response factor can be used in place of a calibration curve.

External Standard Response Factor = $\frac{\text{Total area of Standard}}{\text{Standard amount injected}}$

Internal Standard Response Factor = $\frac{(Ax)\,(Qis)}{(Qx)\,(Ais)}$

Where: Ax = Area response of analyte
Ais = Area response of internal standard
Qis = Amount of internal standard
Qx = Amount of analyte

9.8.5 The calibration curve must be confirmed using the CVS. This second source standard (Section 3.3 of this method) verifies the accuracy of the calibration. The concentration of the CVS should be within the expected concentration range of the samples to be analyzed.

9.8.6 The working calibration curve or response factor must be verified on each working day by the injection of a mid-point CCS. The CCS is a diluted aliquot of the same standard used to initially calibrate the instrument. If the response factor for the CCS varies from the average response factor from the calibration curve (Section 9.8.4 of this method) by more than 25% a new calibration curve must be prepared.

Percent difference = $((R_1 - R_2) / R_1) \times 100$

where: R_1 = Average RF from the calibration curve.
R_2 = Response factor from CCS.

9.9 Retention Time Window

9.9.1 Before establishing windows, be certain that the GC system is within optimum operating conditions (see Section 6.5 of this method). Make three injections of the Retention Time (RT) Window Standard (see Section 7.3.3 of this method) throughout the course of a 72 hour period. Serial injections over less than a 72 hour period result in retention time windows that are too tight.

9.9.2 Calculate the standard deviation of the three absolute retention times for each component and for the surrogate.

9.9.2.1 The retention time window for individual peaks is defined as the average RT plus or minus three times the standard deviation of the absolute retention times for each component.

9.9.2.2 In those cases where the standard deviation for a particular analyte is zero, the laboratory should use ±0.05 min. in place of the standard deviation.

9.9.3 The laboratory must calculate retention time windows for each standard on each GC column and when a new GC column type is installed or instrument conditions changed. The laboratory must retain the data for at least five years and update it at least once a year.

9.10 Gas Chromatograph Analysis: Generally, the analytical batch on a pre-calibrated instrument will follow this flow: Reagent Blank, Retention Time Window Standard, opening CCS, Method Blank, Field Samples, spikes, reps, etc. (20), LFB. Repeat sequence, then end with closing CCS.

9.10.1 Samples are analyzed by GC/FID. Water, with or without methanol extract, to be analyzed for GRO is introduced into the programmed gas chromatograph (Section 9.2) using purge-and-trap sample concentration.

9.10.2 If initial calibration (see Section 9.8 of this method) has been performed, verify the calibration by analysis of a mid-point CCS (see Section 9.8.6 of this method). After the last sample has been analyzed, the same CCS must be analyzed to demonstrate that the analytical system is still in control. With each day's run, open a 24 hour analysis window. This is done by running the Retention Time Window Standard.

9.10.3 An LFB at a concentration representative of the field samples being analyzed must also be run once every 20 samples. If the result does not fall within the range specified in Table 3 of this method, corrective action must be performed and all affected samples re-analyzed.

9.10.4 Calculate the percent difference of the response factor from the mid-point CCS from the mean response factor for each analyte to be quantitated (as in Section 9.8.4 of this method). This is done for GRO as a "group" from the CCS if GRO is to be quantitated (FID) and for each of the components in the Retention Time Window Standard if additional quantitation for BTEX is required (PID). If the response factors have a difference greater than 25%, corrective action must be taken and all samples re-analyzed.

9.10.5 A reagent water blank must be analyzed each day to determine the area generated from normal baseline noise under the conditions prevailing within the 24 hour period. Add up to 300 µL of methanol to the blank when soil or sediment extracts are to be analyzed. The noise area is generated by projecting a horizontal baseline between the retention times observed between the beginning of n-hexane and the beginning of n-decane. This lab control sample is integrated over the GRO area in the same manner as for the field samples and is reported as the reagent blank.

Do not blank subtract. This information is for data interpretation purposes only.

9.10.6 Blanks should also be run after samples suspected of being highly concentrated, to prevent carryover. If the blank analysis shows contamination above the practical quantitation limit, the trap and column must be baked out and subsequent blanks analyzed until the system is shown to retain contaminants at concentrations less than the PQL.

9.10.7 Water samples may be introduced into the system in the following manner:

9.10.7.1 Remove the plunger from a 5-mL syringe and attach a closed syringe valve. Open the sample or standard bottle, which has been allowed to come to ambient temperature and pour the sample into the syringe using caution not to agitate the sample which would result in loss of volatiles. Replace the plunger and compress the sample. Invert the syringe so that the air bubble rises to the top (valve end) of the syringe. Open the syringe valve and vent any residual air while adjusting the sample volume to 5.0 mL. Add 5 µL surrogate spiking solution through the valve bore of the syringe and proceed with analysis.

9.10.7.2 This process of taking an aliquot destroys the validity of the liquid sample for future analysis. Therefore, if there is only one 40-mL vial of sample, the analyst should fill a second syringe at the same time the first one is prepared, in the same manner, to protect against possible loss of sample integrity. This second sample is maintained at 4±2° C with valve closed only until such time as the analyst has determined that the first sample has been analyzed successfully. If a second analysis is needed, it must be from the second syringe and must be analyzed within 24 hours of the opening of the original sample vial. Care must be taken to prevent air from leaking into (and to prevent volatiles from leaking out of) the syringe containing the backup aliquot.

9.10.8 Methanol extracts from soils or sediments must be diluted into reagent water for analysis, as are methanol soluble dilutions. Table 2 of this method is provided at the end of the method to help determine the volume of methanol extract to add to the 5 mL volume of regent water, in order to keep the response of the major constituents in the upper half of the linear range of the curve. The maximum volume of methanol extract usable per 5 mL purge volume is usually 300 µL (this is used in calculating the PQL, Section 3.10 of this method).

9.10.8.1 Follow directions for filling a syringe as outlined in Section 9.10.7.1 of this method, except use reagent water instead of sample. Introduce desired volume of methanol extract by inserting the needle of a microsyringe through the valve opening of the reagent water filled 5-mL

syringe and depressing the micropipette plunger when the needle is well below the surface of the reagent water. The surrogate has already been added (see Section 8.2 of this method). Proceed with analysis.

9.10.9. Dilutions:

9.10.9.1 If the product concentration exceeds the linear range of the method as defined by the calibration curve, the sample (or extract or dilution) must be diluted and reanalyzed. The response of the major peaks should be kept in the upper half of the linear range of the calibration curve.

9.10.9.2 It is most desirable to adjust the volume of extract introduced into the reagent water as in Section 9.10.8.1 of this method to compensate for concentrated sample extracts. However, if that is not possible, the following procedure is appropriate for diluting samples. All steps must be performed without delays until the diluted sample is in a gas-tight syringe:

9.10.9.3 Dilutions may be made in class A volumetric flasks (10-mL to 100-mL seem most useful), or other quantitative glassware with similar accuracy. Select the volumetric flask that will allow for the necessary dilution. Although intermediate dilutions may be necessary for highly concentrated samples, remember that the more transfers the sample makes, the greater the chance components will be lost.

9.10.9.4 Calculate the approximate volume of reagent water to be added to the volumetric flask selected and add slightly less than this to the flask.

9.10.9.5 Inject the proper aliquot of sample from the syringe prepared in Section 9.10.7.2 into the flask. Aliquots of less than 1-mL are not recommended for dilution of water samples using this method. Make sure aliquot is introduced well below the surface of the reagent water in the volumetric flask to minimize sample loss.

9.10.9.6 Dilute the sample to the mark with reagent water, disturbing the surface as little as possible. Cap the flask and invert three times. Repeat the above procedure for additional dilutions. Analyze the diluted sample as in Section 9.10.7 of this method.

9.10.10 Alternative Dilution Technique:

9.10.10.1 Alternatively, the dilutions can be made directly in the glass syringe to avoid loss of volatiles. If diluting methanol extracts, follow Section 9.10.8 of this method using a smaller volume of extract in the 5 mL purge volume or the procedure outlined for the dilution of water

samples.

9.10.10.2 Attach a syringe-syringe valve assembly to the syringe valve on the purging device. Open the syringe valves and inject sample into the purging chamber. Proceed with the analysis. For more information, refer to purge-and-trap methods in SW-846 [1].

9.11 Moisture Determination for Solids

9.11.1 Moisture determinations must accompany all soils data (reported in mg/dry kg) so the client can, at will, determine the results in the original soil condition. Reporting in mg/dry kg can best be done if an unpreserved portion of the sample (collected without methanol) is provided. Because of the potential for high gasoline or related compound concentrations in the soil, all drying should be done under a functioning hood.

9.11.2 To determine percentage of moisture, pre-weigh an aluminum weighing boat. Weigh 5-10 g of the sample into the boat and record both weights to the nearest 0.01 g. Dry the sample overnight in a warm (105° C) oven.

9.11.3 Remove the sample from the oven and cool in a desiccator until the sample reaches room temperature, and weigh to the nearest 0.01 g. Record the weight.

9.12 Calculations:

9.12.1 External Standard Calibration:

The concentration of Gasoline Range Organics in the sample is determined by calculating the absolute weight of analyte purged, from a summation of peak response for all chromatographic peaks, resolved and unresolved, eluting between the peak start time for C_6 (hexane) and the peak start time for C_{10} (decane), using the calibration curve or the calibration factor determined in Section 9.8 of this method and baseline-baseline projection. Refer to Section 9.9 (Retention Time Window.)

The concentration of GRO may be calculated as follows [Method 8000B, 1]:

Aqueous Samples:

$$C_s\ (mg/L) = \frac{(A_x)(D)}{(RF)(Vs)}$$

Where: **C_s** = Concentration of Gasoline Range Organics
RF = Response factor, as described in Section 9.8.4
Ax = Response for the Gasoline Range Organics in the sample, units in

area
Vs = Volume of sample purged, in liters.
D = Dilution factor, if dilution was performed on the sample prior to analysis. If no dilution was made, D = 1, dimensionless.

Solid samples (methanol extraction):

$$C_s \text{ (mg/kg)} = \frac{(A_x)(Vt)(D)}{(RF)(W)(V_i)}$$

Where: Vt = Volume of total extract (µL) (use 10000 µL for standard 10 mL extract volume).
Vi = Volume of extract actually purged (µL)
W = Weight of sample extracted, kg. The dry wet weight is used.
Ax, RF, and D have the same definition as above.
Note: Some chromatographic software programs are capable of performing these calculations with minimal analyst intervention.

9.12.2 Moisture Determination (%)

Moisture (%) = [(A-C)/(A-B)] x 100

Where: A = weight of aluminum boat + wet sample
B = weight of boat
C = weight of boat + dry sample

9.12.3 Internal Standard Calibration.
If internal standard calibration is used, please refer to SW-846 Method 8000B[1].

10. Quality Control (See Table 3 of this method)

10.1 The laboratory must demonstrate, through the analysis of quality control check standards, that the operation of the measurement system is in control. This must include the analysis of QC check samples plus the calculation of average recovery and the standard deviation of the recovery as outlined in this method and in Method 8000B, Section 8.0.

10.2 After successful calibration (Section 9.8 of this method), analyze a reagent blank sample. The reagent blank must be analyzed with every analytical batch. The surrogate recovery must be within established limits (see Table 3 of this method), or within the limits established by the project plan (whichever is more stringent). Also, the mid-point CCS must be analyzed at the beginning and end of each sequence, and compared to the successful calibration as described in Section 9.8.6 of this method, and fall within established limits (see Table 3 of this method). Method detection limits (MDL) must be established as specified in 40 C.F.R. 136, Appendix B, and renewed as specified in Section 3.9 of this method.

10.3 An LFB must be analyzed with every analytical batch, and also run once every 20 samples. The matrix for these samples should be reagent water for batches of aqueous samples or methanol for soil sample batch analyses. The accuracy and precision of the duplicates must be within established limits (see Table 3 of this method).

10.4 With every batch of samples extracted, the reagent blank must be analyzed. The reagent blank must have GRO less than the practical quantitation limit.

10.5 If any of the criteria in Sections 9.8, 10.2, 10.3, and 10.4 of this method are not met, corrective action must be taken before samples are analyzed.

10.6 Calculate the surrogate recovery in each sample. If recoveries are outside established limits (Table 3 of this method), verify calculations, dilutions, and standard solutions. Verify instrument performance.

10.6.1 High recoveries may be due to a co-eluting matrix interference -examine the sample chromatogram.

10.6.2 Low recoveries may be due to adsorption by the sample matrix (i.e., high humus soils).

10.6.3 Low recoveries may be due to a poor purge (clogged purge tube or frit). If this is suspected, check the purge tube with a blank before reanalyzing the sample.

10.6.4 If the surrogate recovery is outside established limits due to suspected matrix effects, GRO results must be flagged. If the surrogate recovery is less than 50%, and the calculated GRO results are within a factor of 2 of the action limit, the laboratory should recommend that the client resubmit the sample for matrix spike and matrix spike duplicate analysis. This is a recommendation, not a requirement of the method, and therefore, the onus is not on the analytical laboratory to absorb the cost of the additional analyses.

10.6.5 If surrogate recovery is low due to moisture dilution, results should be recalculated using a dilution factor determined by the following calculation:

$$\frac{C_1 \times V_1}{[V_1 + [A \times (B/100)]]} = C_2$$

Where: C_1 = concentration of surrogate as measured
C_2 = adjusted value of surrogate
V_1 = volume of methanol preservative
A = total wet weight of sample
B = percent moisture of sample

10.7 Bottle blanks and matrix spikes are recommended for specific sampling programs. Field blanks, trip blanks, field duplicates are required as stated in Chapter 2, Section 9 of the *UST Procedures Manual.*

10.8 Minimum quality control acceptance criteria are in Section 10 of this method. More stringent quality control criteria may be required by specific project plans.

10.9 Corrective Action

10.9.1 Calibration

10.9.1.1 If the initial calibration does not meet the criteria in Sections 9.8.4, 9.8.5, and Table 3 of this method, the instrument must be recalibrated.

10.9.1.2 If the continuing calibration does not meet the criteria in Section 9.8.6 and Table 3, the instrument must be recalibrated.

10.9.2 Surrogates

10.9.2.1 If surrogates are outside established control limits (Table 3 of this method), and are not due to matrix effects, the following assessments and/or correction actions must occur:

A) Check to be sure there are no errors in calculations and that the concentrations of the surrogate and internal standard solutions are correct.
B) Check instrument performance to determine if it is within acceptable guidelines.
C) Recalculate the data and/or reanalyze the extract if any of the above checks reveals a problem.

D) Re-prepare and reanalyze the sample if none of the above resolves the problem.

10.9.2.2 If the surrogate recoveries that are outside the control limits cannot be attributed to lab error, the decision to reanalyze or flag the data should be made in consultation with the client. If all other QC acceptance criteria are met (Section 10 of this method), it is only necessary to re-prepare/reanalyze a sample one time to demonstrate that a poor surrogate recovery is due to matrix effects. A relationship can be established between surrogate recovery and moisture content of organic soils, which may help in diagnosing the cause of poor surrogate recoveries.

10.9.3 Blanks: Additional laboratory and field quality control blanks may be necessary for certain projects to meet the goals of Chapter 2, Section 9 of the *UST*

Procedures Manual.

10.9.3.1 Instrument Blanks:
Instruments must be evaluated with each analytical batch (or daily, whichever is more frequent) and must demonstrate that the analytical system is free from contamination. This is best accomplished by analyzing an Instrument Blank.

10.9.3.2 Trip Blank:
Trip Blanks must be analyzed with each sampling batch IF the results of the field samples show contamination above the maximum contaminant level (MCL). The Trip Blank for AK101 may also serve as the Method Blank and Reagent Blank in some cases.

10.9.3.3 Field Blank:
If the field samples yield GRO above the MCL, and contamination is found above the PQL in the Trip Blank, a Field Blank should be analyzed to identify whether the source of contamination originated in the field sample collection procedure, during travel or during storage in the laboratory.

Note: Blanks are reported by value. DO NOT BLANK SUBTRACT. This information is for data quality assessment purposes only.

10.9.4 Laboratory Fortified Blanks

10.9.4.1 If the analyte recovery from the LFBs is outside the established recovery limits (Table 3 of this method), the following assessments and/or corrective actions must occur:

A) Check to be sure there are no errors in calculations and that the concentration of the analyte solution is correct.
B) Check instrument performance to determine if it is within acceptable guidelines.
C) Recalculate the data and/or reanalyze the extract if any of the above checks reveals a problem.
D) Re-prepare and reanalyze the samples if none of the above resolves the problem.

10.9.4.2 If the relative percent difference between the LFB results exceeds the control limits, but meets the percent recovery criteria (Table 3 of this method), the following assessments and/or corrective actions must occur:

A) Check to be sure that there are no errors in calculations, and that the same amount and source of analyte solution, solvent and water were used for both samples in the set.
B) Check to determine if instrument performance is still within acceptable

guidelines, and that conditions did not change during the course of the batch analysis.

C) Recalculate the data if calculation error is suspected.

D) Repeat the LFB duplicate extraction and analysis, along with a representative number of samples (10% of the samples from the batch OR 1 sample, whichever is more) from the analytical batch with the failed LFB RPD. The re-analysis of the field samples is to demonstrate comparability of the extraction/analysis conditions at the time of re-extraction and analysis to those at the time of the failed QC.

11. Method Performance

11.1 Performance evaluation data and single-lab method performance data for the methanol extraction method in various soil types is presented below. Additional method performance data is available through the State of Alaska, Department of Environmental Conservation.

11.2 Results for gasoline spikes (Methanol extraction purge and trap, soils)

Matrix	Gasoline Spike Amount mg/kg	Percent Recovery
PE Samples	1190	89
Houston Black Clay[1]	50	68
Houston Black Clay[1]	50	66
Norwood Loam[1]	50	60
Norwood Loam[1]	50	57
Ottawa Sand[2]	50	97
Ottawa Sand[2]	50	96
Marine Sand[2]	50	94
Glacial Clay[2]	50	68
River Sediment[2]	50	53
Marine Sediment[2]	50	132
Forest Loam, muskeg, tundra[2,3]	50	28

1. Analyses performed by Rocky Mountain Analytical. Gasoline used = API PS6.
2. Analyses performed by State of Alaska, ADEC Laboratory. Gasoline used = GCS.
3. All highly organic, high moisture soils matrices showed less than 30% analyte recovery.

11.3 The method detection limit calculated according to 40 C.F.R. 136, Appendix B, was 0.5 mg/kg GRO as gasoline for the methanol extraction of soils and 0.01 mg/L GRO as gasoline for waters.

12.References

1. USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, 3d Edition; Methods 5030, 8000, 8015, 8020, and 8021B.

2. USEPA, *Sampling and Analysis of Gasoline Range Organics in Soils*, American Petroleum Institute Pub. #4516, October 1991.

3. USEPA, *Evaluation of Proposed Analytical Methods to Determine Total Petroleum Hydrocarbons in Soil and Groundwater*, prepared by Midwest Research Institute for USEPA Office of Underground Storage Tanks, August 14, 1990.

4. Urban, M.J., J.S. Smith, E.K. Schultz, R.K. Dickson, *Volatile Organic Analysis for a Soil, Sediment or Waste Sample* in Fifth Annual Waste Testing and Quality Assurance Symposium, USEPA, July 24-28, 1989.

5. Siegrist, R.L., and P.D. Jenssen, *Evaluation of Sampling Method Effects on Volatile Organic Compound Measurements in Contaminated Soils*, Environmental Science and Technology, Vol. 24, November 1990.

6. Fitzgerald, John, *On-site Analytical Screening of Gasoline Contaminated Media Using a Jar Headspace Procedure* in Petroleum Contaminated Soils, Vol. 2, 1989.

7. Senn, R.B., and M.S. Johnson, *Interpretation of Gas Chromatographic Data in Subsurface Hydrocarbon Investigations*, Ground Water Monitoring Review, 1987.

8. Hughes, B.M., D.E. McKenzie, C.K. Trang, L.S.R. Minor, *Examples of the Use of and Advanced Mass Spectrometric Data Processing Environment for the Determination of Sources of Wastes* in Fifth Annual Waste Testing and Quality Assurance Symposium; USEPA, July 24-28, 1989.

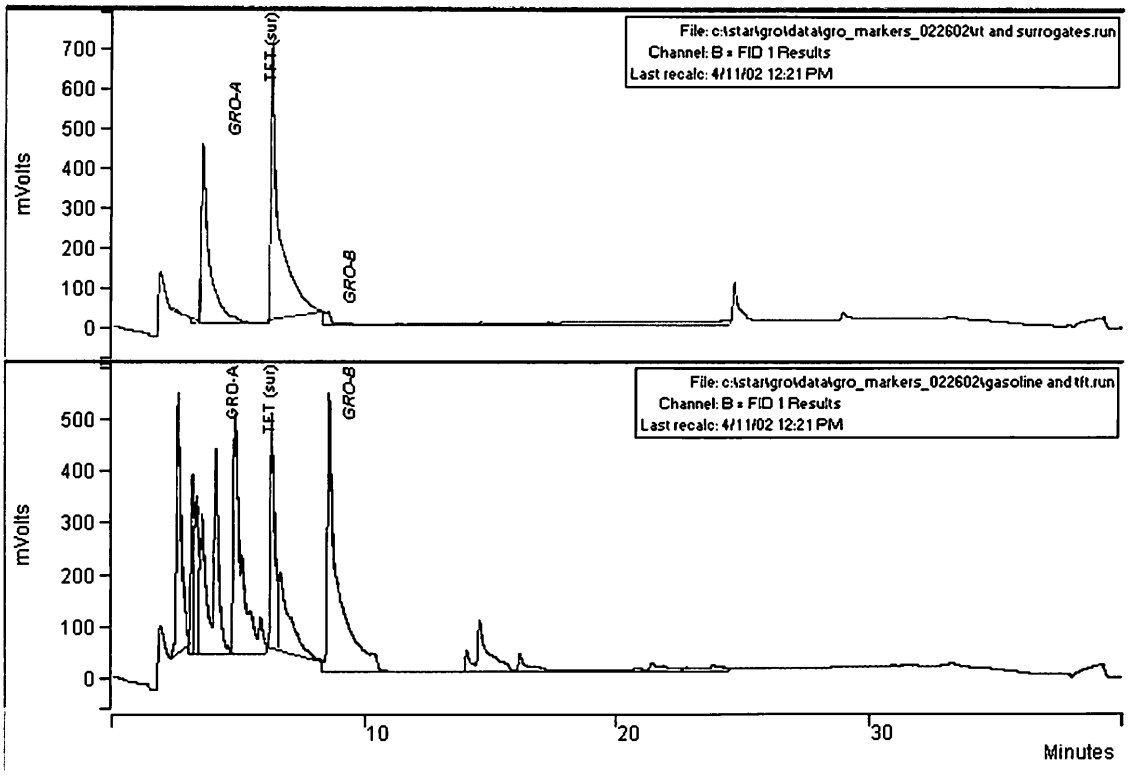
9. *Laboratory Study on Solubilities of Petroleum Hydrocarbons in Groundwater*, American Petroleum Institute Pub #4395, August 1985.

10. *Volatile Organic Analysis for a Soil, Sediment or Waste Sample (The Methanol Method)*, a symposium prepared by James S. Smith, Ph.D. for the State of Alaska, Department of Environmental Conservation, Underground Storage Tank/Leaking Underground Storage Tank program, August 16, 1993.

11. Carrell, Bob, *NWTPH-Gx, Volatile Petroleum Products Method for Soil and Water*, Manchester Environmental Laboratory, Dept. of Ecology, State of Washington, December 1996.

12. USEPA, Guidelines for Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act (40 C.F.R.136), Part VIII, October 26, 1984.

Figure 1. Gasoline Range Organics



Hexane, a,a,a-TFT, and Decane (above)
Gasoline and a,a,a-TFT (below)

Column:
HP-5MS, 30 meters, 32 microns ID
Carrier Gas Hydrogen
Program: 1. Hold at 30 deg C for 4.42 minutes.
2. 2 deg/min to 77 deg C
3. 50 deg/min to 230 deg.
4. Hold at 230 deg 1 minute.

Purge and desorb conditions as recommended in the method

Method AK 101 - Table 1
Recommended Purge and Trap Operating Parameters[a]
For GRO/8021B

Parameter	Setting
Purge Gas	Nitrogen or Helium
Purge Gas Flow Rate (mL/min.)	40
Purge Time (min.)	11-12
Purge Temperature (°C)	Ambient
Desorb Temperature (°C)	140-180
Back Flush Inert Gas Flow (mL/min.)	20-60
Desorb Time (min.)	3-6
Trap Bake-out Time (min.)	8-12

[a] These parameter are recommendations. Use the settings that are proper for the trap used and which yield optimal results.

Method AK 101 - Table 2
Quantity of Methanol Extract Needed for
Analysis of Soils and Sediments

Approximate Concentration, GRO (mg/kg)[a]	Volume of Methanol Extract (µL)[b]
5-100	300
200	50
1000	10
5000	100 µL of 1/50 dilution[c]

Calculate appropriate dilution factor for concentrations exceeding this table.

a. This number is determined by sample pre-screening.

b. The volume of methanol added to 5 mL of water being purged should be kept constant. Therefore, add to the 5-mL syringe whatever volume of methanol is necessary to maintain a total volume of 300 µL of methanol for each blank, sample and control.

c. Dilute an aliquot of the methanol extract and then take 300 µL for analysis.

Method AK 101 - Table 3
Acceptance Criteria for Quality Control
Based on Approved Laboratory PE Performance, 1996.

ANALYTE	SPIKE CONCENTRATION		CONTROL LIMITS	
	Water (mg/L)	Soil (mg/kg)	% Recovery	Relative % Difference
Lab-Fortified Blanks				
Gasoline Range Organics	0.1 – 1.	5 - 100	60-120	20
Laboratory Sample Surrogate Recovery				
α,α,α-Trifluorotoluene or Bromofluorobenzene	0.05	2.5	60-120	
Field Sample (based on Approved Laboratory data packages, 1996) **Surrogate Recovery**				
α,α,α-Trifluorotoluene or Bromofluorobenzene	0.05	2.5	50-150	
Continuing Calibration/ Calibration Verification Standards				
See Section 9.8.6	1.0		75 - 125	

The quality control criteria listed in this table represent the minimum acceptable levels, using highly organic soil matrices. Higher performance may be required on some projects

Method AK 102

For Determination of Diesel Range Organics
Version 04/08/02

1. Scope and Application

1.1 Objectives

1.1.1 This method is designed to measure the concentration of Diesel Range Organics (DRO) in water and soil. This corresponds to an n-alkane range from the beginning of C_{10} to the beginning of C_{25}, and a boiling point range of approximately 170° C to 400°C. (See Figure 1 of this method)

1.1.2 Components with boiling points greater than the start of C_{25} present in products such as motor oils or lubricating oils are detectable under the conditions of the method.

1.2 Quantitation Limits

Practical quantitation limits (PQL) for this method for analysis of DRO must not exceed 20 mg/kg for soils and 800 µg/L for waters.

1.3 Dynamic Range

Dilutions should be performed as necessary to put the chromatographic envelope within the linear range of the method. Linear range is dependent in part upon column type, detector sensitivity, and injection volume. Typically, the approximate range is 1 mg/L to 100 mg/L as diesel.

1.4 Experience

This method is based on a solvent extraction, gas chromatography (GC) procedure. This method should be used by, or under the supervision of, analysts experienced in the use of solvent extractions and gas chromatographs as quantitative tools.

2. Method Summary

2.1 This method provides gas chromatographic conditions for the detection of semi-volatile petroleum products such as diesels. Other non-petroleum compounds with similar characteristics and boiling points, may also be detected with this method. One liter of water or 25 grams of soil is the recommended sample size. Samples must be spiked with a surrogate compound and extracted with methylene chloride. The extract is dried and concentrated. An aliquot of the extract must be injected into a capillary column gas chromatograph equipped with a flame ionization detector (FID), which has been temperature programmed to facilitate separation of organic compounds. Quantitation must be performed by comparing the total chromatographic area between and including the peak start of C_{10} to the peak start of C_{25}, including both resolved and unresolved

components, based on FID response compared to a diesel calibration standard (see Section 3.2 of this method). Integration must be performed using forced baseline-baseline integration.

2.2 This version of the method was developed by Mary Jane Pilgrim, Ph.D. and is based, in part, on a modification of the American Petroleum Institute consensus "Method for the Determination of Diesel Range Organics," Revision 2, 2/5/92 [11], supplemented with information gathered by the State of Alaska, Department of Environmental Conservation, State Chemistry Laboratory, with support from the Storage Tank Program. It is based in part on EPA Methods 8000 and 8 100, SW- 846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* [1], adopted by reference in 18 AAC 78.090(i), Method OA-2 [2] and work by the EPA Total Petroleum Hydrocarbons Method Committee [3], and the State of Oregon, "Total Petroleum Hydrocarbon Methods" QAR 340-122-350 dated December 11, 1990.

3. Definitions

3.1 Diesel Range Organics (DRO): All chromatographic peaks, both resolved and unresolved, eluting between the peak start of n-decane (C_{10}) and the peak start of n-pentacosane (C_{25}) Quantitation is based on direct comparison of the area within this range to the total area over the same (C_{10} - C_{25}) range of the calibration standard as determined by FID response using forced baseline-baseline integration. Surrogate peak areas shall be determined by valley to valley integration.

3.2 Diesel Calibration Standard (DCS): Commercial #2 diesel fuel or equivalent hydrocarbon mixture in which greater than 95% of the hydrocarbon mass elutes within the diesel change diluted to appropriate concentrations in methylene chloride. The DCS serves as a calibration standard for DRO.

3.3 Surrogate: Ortho-terphenyl or equivalent. The surrogate must be spiked into all extracted samples and standards prior to extraction.

3.4 Calibration Verification Standard (CVS): A quality control standard, prepared as in Section 3.2 of this method, but with a diesel range hydrocarbon mixture from a source other than that used to prepare the Diesel Calibration Standard. It is used by the laboratory to verify the accuracy of calibration. Greater than 95 % of the hydrocarbon mass must elute between the diesel range.

3.5 Laboratory Fortified Blank (LFB): A method blank sample spiked with a commercial #2 diesel fuel the same as that used to make the Diesel Calibration Standard (see Section 3.2 of this method). The spike recovery is used to evaluate method control (see Table 1 of this method).

3.6 Retention Time Window Standard: A mixture of the normal alkanes n-decane and n-pentacosane (C_{10} and C_{25}) which is analyzed once every 24 hour "day" or with each batch

of samples, whichever is less frequent, not to exceed 20 samples per batch. This standard serves to define the retention time window for DRO.

3.7 Internal Standard: Alpha androstane, used to normalize DRO concentrations. Use of an internal standard is recommended, but not required.

3.8 Standard Soil: Ottawa sand, Norwood loam, Houston black clay, or other standard soil with characteristics which match the field samples as closely as possible, used in quality control samples.

3.9 Continuing Calibration Standard (CCS): A mid-range working standard diluted from the Diesel Calibration Standard, used to verify that the analytical system is operating in a manner comparable to that at the time of initial calibration.

3.10 Method Detection Limit (MDL): The minimum concentration of a compound that can be measured and reported with 99 percent confidence that the value is greater than zero, determined from analysis of a sample in a given matrix containing the analyte. (See 40 C.F.R. 136, Appendix B, for method of determining method detection limit.) Each laboratory must demonstrate and periodically update method detection limits for each analyte of interest.

3.11 Practical Quantification Limit (PQL): is defined as 5 times the MDL.

3.12 Method Blank – also known as a procedural blank demonstrates that the apparatus and reagents used to perform the method are free from contamination.

3.13 Instrument Blank – demonstrates that the instrument is free from contamination.

3.14 Solvent Blank – demonstrates that the solvent (in this case methylene chloride) used in the method is free from contamination. It should not go through the procedure. It may also serve as an instrument blank.

3.15 Other terms are as defined in SW-846 [1].

4. Interferences

4.1 Other organic compounds including, but not limited to, animal and vegetable oil and grease, chlorinated hydrocarbons, phenols, phthalate esters and biogenic terpenes are measurable under the conditions of this method. Heavier petroleum products such as lubricating oil and crude oils also produce a response within the retention time range for DRO. As defined in the method, the DRO results include these compounds.

4.2 Method interferences may be reduced by washing all glassware with hot soapy water and then rinsing it with tap water, methanol, and methylene chloride. Heating the glassware to reduce contaminants should not be necessary if this cleaning method is followed. At least

one blank must be analyzed with each extraction batch to demonstrate that the laboratory samples are free from method interferences.

4.3 High purity reagents must be used to minimize interference problems.

4.4 Contamination by carryover can occur whenever high-level and low-level samples are sequentially analyzed. Whenever an unusually concentrated sample is encountered, it should be followed by analysis of a solvent blank to check for instrument contamination.

5. Safety Issues

5.1 The toxicity or carcinogenicity of each reagent in this method has not been precisely defined. However, each chemical compound should be treated as a potential health hazard. Exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of Occupational Safety and Health Administration (OSHA) regulations regarding the safe handling of the chemicals specified in this method. A reference file of Material Safety Data Sheets (MSDS) should also be made available to all personnel involved in chemical analysis. Additional references to laboratory safety should be available and identified for use by the analyst.

5.2 A hearing protection device should be used when performing sonication.

6. Apparatus and Materials

(Unless otherwise indicated, all apparatus and materials are suggested only.)

6.1 Glassware

6.1.1 4-oz. amber glass wide mouth jars with Teflon-lined screw caps.

6.1.2 Separatory funnel – 2000-mL with Teflon stopcock.

6.1.3 Continuous liquid-liquid extractor - equipped with Teflon or glass connecting joints and stopcocks requiring no lubrication (Hershberg-Wolf Extractor, Ace Glass Company, Vineland, New Jersey, P/N6841-10, or equivalent).

6.1.4 Concentrator tube. Kuderna-Danish 10-mL graduated (Kontes K-570050-1025 or equivalent). Calibration must be checked at the volumes employed in the test. Ground glass stopper is used to prevent evaporation of extracts.

6.1.5 Evaporative flask, Kuderna-Danish 500-mL (Kontes K-570001-0500 or equivalent). Attach to concentrator tube with springs.

6.1.6 Snyder column, Kuderna-Danish three ball macro (Kontes K-503000-0121 or

equivalent). Rotary evaporation set-up may be used alternatively.

6.1.7 Jars: One liter amber glass, with Teflon lined screw caps.

6.1.8 Two mL glass vials with Teflon-lined cap (autosampler vials).

6.1.9 Disposable pipettes: Pasteur.

6.1.10 Graduated cylinders: 250-mL.

6.1.11 Glass or Teflon funnels.

6.2 Boiling chips –Boiling chips must be decontaminated in a manner appropriate for the material.

6.3 Micro syringes 1-µL, 5-µL, 10-µL, 25-µL, and 100-µL.

6.4 An analytical balance capable of accurately weighting 0.0001 g should be used for preparing standards and percent moisture determination. A top-loading balance capable of weighing to the nearest 0.01 g should be used for sample preparation and percent moisture determination.

6.5 Stainless steel spatula.

6.6 Gas Chromatography

6.6.1Gas Chromatography: Analytical system including appropriate gas supply and all required accessories, including a Flame Ionization Detector (FID), column supplies, gases, and syringes. A data system capable of determining peak areas using a forced baseline – baseline projection is required. A data system capable of storing and reintegrating chromatographic data is recommended.

6.6.2 Columns

6.6.2.1 Column 1:HP5MS 30 M x 0.32 mm 0.25 micron film thickness or equivalent.

6.6.2.2 Other Columns may be used - capillary columns may be essential to achieve the necessary resolution. The column must resolve C_{10} from the solvent front in a midrange DCS or CVS must resolve C_{24} from C_{25}.

6.7 Sonication.

6.7.1 Ultrasonic cell disrupter: A horn-type sonicator equipped with a titanium tip should be used. A Heat Systems-Ultrasonics, Inc., Model W-385 (475 watt)

sonicator or equivalent (power wattage must be a minimum of 375 with pulsing capability and No. 200 1/2inch Tapped Disrupter Horn) plus No. 2073/4inch Tapped Disrupter Horn, and No. 419 1/8 inch Standard tapered Microtip probe.

6.7.2 A Sonabox or equivalent is recommended with the above disrupter for decreasing sound (Heat Systems-Ultrasonics, Inc., Model 432 13 or equivalent).

6.8 Soxhlet extraction apparatus as described in SW-846, Method 3540 [1].

6.9 Nitrogen evaporator with high purity (grade 4.5 or equivalent) nitrogen gas source.

7. Reagents and Standards

7.1 Reagent Water: Water that has been shown to be free from target analytes and interfering substances.

7.2 Methylene Chloride - pesticide grade or equivalent. At a minimum, the solvents must be shown to be free from DRO.

7.3 Sodium Sulfate - (ACS grade) granular, anhydrous. Purify by heating at 400°C for 4 hours in a shallow tray or by extracting three times with methylene chloride and drying at 100 ±5° C. Incomplete cleaning of sodium sulfate can result in DRO contamination of samples.

7.4 Stock Standard Solutions - Prepare the following stock standards. Unless noted, all are prepared in the methylene chloride listed in Section 7.2 above. Standard preparation should follow guidelines in SW-846 [1]. All standards prepared by the laboratory must be stored without headspace at -10 to -20°C and protected from light. Marking of the meniscus is helpful in maintaining stock standard integrity. Standards must be replaced within 6 months of preparation. Standards should be checked regularly to assure their integrity. Standards, which are purchased pre-made from commercial suppliers, may be kept for the life, and under the conditions, specified by the manufacturer if different than described in this paragraph.

7.4.1 Optional Stock Internal Standard: 1000 µg/mL 5 alpha-androstane. Other internal standards may be used provided they do not interfere with the DRO components.

7.4.2 Recommended Surrogate Control Standard: 200 µg/mL ortho-terphenyl (OTP). A working solution is made at 20 µg/mL (recommended concentration) in methylene chloride.

7.4.3 Diesel Calibration Standard: Diesel #2 is used to prepare stock calibration standards in methylene chloride. No fewer than 3 concentrations of this DCS are

used for instrument calibration. A five-point calibration curve is recommended. Other than one standard concentration near the practical quantitation limit, the expected range of concentrations found in project samples should define the working range of the GC. A mid-range dilution of this blend serves as the Continuing Calibration Standard.

7.4.4 Retention Time Window Standard: A stock solution of C_{10} and C_{25} each at a level of at least 2000 µg/mL. This blend of alkanes serves as a retention time window defining mix for DRO.

7.4.5 Stock Calibration Verification Standard (CVS): Provide a stock source of commercial diesel #2 other than that used to prepare the DCS, as described in Section 7.4.3 of this method. A working solution is made at a recommended concentration of 5000 µg/mL in methylene chloride.

8. Sample Collection, Preservation, Containers, and Holding Times

8.1 Water samples are collected in one liter amber glass containers with Teflon lined screw caps and acidified to pH 2 or less with HCl.

8.2 Soils are collected in a core tube, or 4 or 8 oz amber glass jar with Teflon-lined lid. The samples are stored at 4° ±2° C from the time of collection until extraction. Extraction must be performed on waters and soils within 14 days [1]. All analyses of extracts must take place within 40 days.

8.3 Soil samples to be analyzed for both volatiles and DRO may be collected in the same, methanol preserved container and stored as for GRO (AK101). If this option is selected, the mechanics of the collection, preservation, and container should be discussed with the client before sampling kit preparation. DRO extraction and analysis must still meet the requirements of Section 8.2, above.

8.4 Performance Evaluation (PE) Samples must be obtained from a supplier approved by The NELAC Institute (TNI) or a supplier approved to ISO 17043 standards.

9. Procedure

9.1 Sample Preparation

The preferred method for water extraction is SW-846 Method 3510 (Separatory Funnel Liquid-Liquid Extraction), and for soil samples Method 3540 (Soxhlet Extraction). However, any sample extraction technique which meets the quality assurance requirements specified in Section 10 and Table 1 of this method may be used, and the extraction solvent is methylene chloride.

9.1.1 Water extraction - Separatory Funnel.

9.1.1.1 Measure a 1-L portion of the sample and transfer to a 2-L separatory funnel. If the sample is in a 1-L or smaller bottle, mark the water meniscus on the side of the sample bottle. Measure the exact volume by adding tap water to the bottle to the marked level, and then transferring the volume of tap water to a 1-L graduated cylinder. Use no more than 1-L of sample per 2-L separatory funnel. For blanks and quality control standards, pour 1-L of reagent water (see Section 7.1 of this method) into the separatory funnel.

9.1.1.2 Check and note the pH of the sample. If the field samples have been preserved with HCl, it is recommended that the quality control samples and blanks be preserved in the same way.

9.1.1.3 Add 1 mL of surrogate standard (Section 7.4.2 of this method, recommended level of 20 µg/mL if o-terphenyl is used).

9.1.1.4 For every batch or 20 samples extracted (whichever is more frequent), prepare duplicate LFBs. Daily or for every 20 samples (whichever is more frequent), prepare a method blank using 1-L of reagent water. Surrogate must be added to both the LFBs and the method blank.

9.1.1.5 For samples, add 60 mL methylene chloride to the sample bottle to rinse the inner walls after the sample has been transferred to the separatory funnel. **Do not** cap and shake the bottle, rinse the glass only; then transfer the solvent to the separatory funnel. Extract the sample by shaking it for no less than two minutes with frequent ventilation.

9.1.1.6 Allow the layers to separate (approximately 10 minutes rest after shaking).

9.1.1.7 Drain the bottom layer (methylene chloride).

9.1.1.8 Repeat the extraction twice more, using a 60 mL aliquot of methylene

chloride each time. Collect the solvent in the same vessel as described in Section 9.1.1.7 of this method.

9.1.1.9 Concentrate extracts to 1 mL at a temperature not to exceed 55° C or that recommended by the manufacturer of concentration apparatus being used. Transfer extracts to GC vials for analysis. Extracts should be stored in a freezer at <10° C. Record the information for the extraction and concentration steps.

Note: The concentration step is critical; losses of target compounds can occur if care is not taken.

9.1.1.10 If the extract is highly colored, forms a precipitate, or stops evaporating, the final volume should be higher (5-10 mL). Transfer to a labeled vial of appropriate size with Teflon-lined cap, mark the meniscus. Extracts should be stored in a non-frost free freezer at <-10° C.

9.1.1.11 Record information for the extraction and concentration steps.

Note: The extraction and concentration steps must be performed under a hood. Methylene chloride a potential health hazard (see MSDS).

9.1.2 Soil Preparation - Soxhlet Extraction

9.1.2.1 Decant any water layer that may accompany the solid layer in the sample. Note what percent of the sample the water represents and, if sufficient volume exists, extract and analyze the water for DRO. Also note the apparent condition of the sample (presence of foreign materials, variable particle size, presence of oil sheen, multiple phases, etc.).

9.1.2.2 Weigh 10 g to 30 g of the original sample into an extraction thimble. Add an equal weight of anhydrous sodium sulfate and stir the mixture well with a stainless steel or Teflon® spatula. The sample should have a grainy texture - if the sample clumps, add more sodium sulfate until a grainy texture is achieved and note the addition. (Do this for all samples and standards.)

9.1.2.3 Place loaded thimbles in extractors and add surrogate to both field and quality control samples.

9.1.2.4 Add spiking solution to the duplicate LFBs. These quality control samples should contain 10 g of methylene chloride rinsed Ottawa Sand or alternative standard soil. In addition, prepare a method blank.

9.1.2.5 Add 300 mL of methylene chloride to the 500-mL extraction flask. Less extraction solvent may be used if the quality control criteria specified in Section 10 and Table 1 are met. Also add a few methylene chloride washed, boiling chips to the flask. Connect the extractor to the flask and the condenser to the extractor. Allow samples to extract for 18-24 hours, or as long as necessary to achieve optimum surrogate recovery. Be sure that coolant is flowing around the condensers.

9.1.2.6 Recommendation: After extraction, dry the extract with anyhydrous sodium sulfate. (This assures that the extract is water-free before concentration.)

9.1.2.7 Transfer extract into a clean concentration vessel and concentrate extracts to 1 mL at a temperature not to exceed 55° C or that recommended by the manufacturer of concentration apparatus being used. Transfer extracts to GC vials for analysis. Extracts should be stored in a freezer at <10° C. Record the information for the extraction and concentration steps.

9.1.3 Moisture Determination for Solids

9.1.3.1 Moisture determinations must accompany all soils data (reported in mg/dry kg) so the client can, at will, determine the results in the original soil condition. Because of the potential for high petroleum compound concentrations in the soil, all drying should be done under a functioning hood.

9.1.3.2 To determine percentage of moisture, pre-weigh an aluminum weighing boat. Weigh 5 -10 g of the sample into the boat and record both weights to the nearest 0.01 g. Dry the sample overnight in a warm (105°C) oven.

9.1.3.3 Remove the sample from the oven and cool in a desiccator until the sample reaches room temperature, and weigh to the nearest 0.01 g. Record the weight.

9.1.4 Dilution Technique

9.1.4.1 This is used for product or waste samples for which extraction is not appropriate and which are soluble in methylene chloride.

9.1.4.2 Weigh 1 g of sample into a 10-mL volumetric flask. Dilute to 10-mL with methylene chloride. Transfer to a 12 mL vial with a Teflon lined lid. Mark meniscus and store at <4°C. (Refer to EPA SW-846 Method 8270C for storage temperature.)

9.2 Gas Chromatography

9.2.1 Conditions (Recommended):
Set helium column pressure to 20#. Set column temperature to 40° C for 2 minutes, then ramp at a rate of 12° C/min to 320° C and hold for 15 min. (run time = 36 minutes). Set FID Detector to 320° C and injector to 280° C.

9.2.2 Performance Criteria: GC run conditions and columns must be chosen to meet the following criteria:

9.2.2.1 Resolution of the methylene chloride solvent front from C_{10}.

9.2.2.2 The separation number, TZ, should be greater than 15 for C_{24} and C_{25}, if RRO is to be analyzed concomitantly.

$$TZ = [(\text{retention time } C_{25} - \text{retention time } C_{24})/ (W\ ½ \text{ of } C25 + W\ ½ \text{ of } C24)] - 1$$

Where "W½" = peak width at half-height

9.2.2.3 The column must be capable of separating typical diesel components from the surrogate and internal standards. In particular, there are potential problems with the resolution of n-C_{19} from ortho-terphenyl and n-C_{21} from 5 alpha-androstane at varying relative concentrations.

9.3 Calibration

9.3.1 Calibrate the GC, set up as in Section 9.2 of this method. A minimum of three concentrations of DCS (five concentrations are recommended).

9.3.2 Choose DCS concentrations to cover the DRO range expected in the samples, or the linear range of the instrument, whichever is less. Linearity of the calibration curve at the PQL must be determined.

9.3.3 Curve fit must be linear regression with a R^2 of 0.995 or better, quadratic fit with a R^2 of 0.995 or better, or if using response factors, the average percent relative standard deviation (%RSD) is less than 25% over the working range.

9.3.4 The calibration curve must be confirmed using the CVS (see Section 7.4.5 of this method). This standard verifies the accuracy of the calibration. The concentration of the CVS should be within the expected concentration range of the samples to be analyzed. The working RF or calibration curve must be verified on each working day (24 hours) by the injection of a CCS (see Section 7.4.3 of this method) at a concentration mid-point on the calibration curve. The CCS is a diluted aliquot of the same standard used to initially calibrate the instrument. If the response for the CCS

varies from the predicted response by more than 25%, a new calibration curve must be prepared.

9.4 Retention Time Window Definition:

9.4.1 Before establishing windows, be certain that the GC system is within optimum operating conditions (see Section 6.6 of this method). Make three injections of the Retention Time Window Standard (see Section 7.4.4 of this method) and surrogate throughout the course of a 72 hour period. Serial injections over less than a 72 hour period result in retention time windows that are too tight.

9.4.2 Calculate the standard deviation of the three absolute retention times for decane and pentacosane and the surrogate.

9.4.2.1 The retention time (RT) window for individual peaks is defined as the average RT plus or minus three times the standard deviation of the absolute retention times for each component.

9.4.2.2 In those cases where the standard deviation for a particular analyte is zero, the laboratory should use ±0.05 min. in place of the standard.

9.4.3 The laboratory must calculate retention time windows for each standard on each GC column and whenever a new GC column is installed or instrument conditions changed. The data must be retained by the laboratory for at least a year.

9.4.4 Retention time windows must be verified regularly and updated no less frequently than once a year.

9.5 Gas Chromatograph Analysis

9.5.1 Samples are analyzed by GC/FID. Optimum injection volumes (2 µL using the conditions established in Section 9.2 of this method) must be established for specific instrument conditions.

9.5.2 For internal standard calibration, the internal standard is spiked into each sample and standard at a concentration of 200 µg/mL of sample extract. Twenty µL of 5-alpha androstane stock at 1000 µg/mL may be spiked into the 1 mL final volume or a corresponding amount may be added to an aliquot of the final extract. (Note: **DRO values >2000 µg/mL may lead to measurement bias due to coelution with the internal standard.)** Internal standard calibration should not be used when DRO exceeds 5,000 µg/mL in the final extract.

9.5.3 If initial calibration (see Section 9.3 of this method) has been performed, verify the calibration by analysis of a mid-point CCS. With each day's run, open a 24 hour analysis window. This is done by running the Retention Time Window

Standard (Section 7.4.4 of this method).

9.5.4 Calculate the percent difference of the response factor from the mean response factor as in Section 9.3.2 of this method. This is done for DRO as a group from the CCS. If the response factor has a percent difference greater than 25%, corrective action must be taken.

9.5.5 A solvent blank (methylene chloride) may be analyzed each day to determine the area generated from normal baseline noise under the conditions prevailing in the 24 hour period. This area is generated by projecting a horizontal baseline between the retention times observed for the peak start of C_{10} and the peak start of C_{25}. This blank is integrated over the DRO area in the same manner as for the field samples and is reported as the solvent blank. (Refer to Section 4 of this method) **Do not baseline subtract. This information is for data interpretation purposes only.**

9.5.6 Blanks should also be run after samples suspected of being highly concentrated to prevent carryover. If the blank analysis shows contamination above the practical quantitation limit, the column must be baked out and subsequent blanks analyzed until the system is shown to retain contaminant at concentrations less than the PQL.

9.5.7 If the DRO concentration exceeds the linear range of the method (as defined by the range of the calibration curve) in the final extract, corrective action must be taken. The sample should be diluted or external standard calibration should be used. The response of the major peaks should be kept in the upper half of the linear range of the calibration curve

9.6 Calculations:

9.6.1 Percent Moisture Calculation for Soils

% Moisture = [(A-C)/(A-B)] x 100

Where: A = weight of boat + wet sample
B = weight of boat
C = weight of boat + dry sample

Note: Make sure drying oven is placed under a hood. Heavily contaminated soils will produce strong organic vapors.

9.6.2 Internal Standard Calibration: The concentration of DRO in the sample must be determined by calculating the absolute weight of analyte chromatographed from a summation of peak response for all chromatographic peaks eluting between the peak start of n-decane and the peak start of n-pentacosane, using the calibration curve or the response factor determined in Section 9.3 and Section 9.4 of this

method (Retention Time Window Definition). The concentration of DRO is calculated as follows:

Aqueous/Soil samples:

$$Cs = \frac{(Ax)(Cis)(D)(Vt)}{(Ais)(RF)(Vs)}$$

Where: Cs = Concentration of DRO (mg/L or mg/kg).
Ax = Response for the DRO in the sample, units in area.
RF = Response Factor from CCS (see Section 9.3.3).
Ais = Response for the internal standard, units same as for Ax.
Cis = Internal standard concentration (mg/mL).
Vt = Volume of final extract in mL.
D = Dilution factor, if dilution was performed on the sample prior to analysis. If no dilution was made, D = 1, dimensionless.
Vs = Amount of sample extracted in L or kg.

9.6.3 To calculate mg/dry kg for soil samples,

$$\text{mg/dry kg DRO} = \frac{Cs}{1-(\%\ \text{moisture}/\ 100)}$$

The % moisture calculation must be included in the data package (see Section 9.6. 1). Some software programs are capable of performing these calculations with minimal analyst intervention.

9.6.4 External Standard Calibration:

Aqueous/Soil samples:

$$Cs = \frac{(Ax)\ (A)\ (Vt)\ (D)}{(As)\ (Vs)}$$

Where: **Cs** = Concentration of DRO (mg/L or mg/kg).
Ax = Response for the DRO in the sample, units in area.
As = Response for the external standard, units same as for Ax.
A = External standard concentration (mg/mL).
Vt = Volume of Final extract in mL.
D = Dilution factor, if dilution was performed on the sample prior to analysis. If no dilution was made, then D = 1, dimensionless.
Vs = Amount of sample extracted in L or kg.

9.6.5 Some software programs are capable of performing Sections 9.6.1 and 9.6.3 of this method, with minimal analyst intervention. Additionally, some software programs can "update" a calibration curve based on the response of the CCS. If a calibration curve is

updated in this manner, a valid CVS must be analyzed and results must fall within the Quality Control Criteria specified in Section 10 and Table 1 of this method before field samples can be analyzed.

10. Quality Control

10.1 Curve Verification Standard (CVS)

10.1.1 The CVS is not extracted.

10.1.2 The CVS is analyzed once with calibration standards to verify calibration curve.

10.1.3 The CVS recovery requirement is 75-125% of true value.

10.2 Continuing Calibration Samples (CCS)

10.2.1 The CCS is not extracted.

10.2.2 The CCS is analyzed at the start and end of an analytical batch and for every 20 samples in that batch.

10.2.3 The CCS recovery requirement is 75-125% of true value.

10.3 Blanks

10.3.1 Instrument Blank may be analyzed with each analytical batch to demonstrate that the system is free from contamination.

10.3.2 Method Blank must be analyzed with each extraction batch.

10.3.3 BLANK SUBTRACTION IS NOT ALLOWED. Blanks are reported by value. This information is for data quality assessment purposes only.

10.3.4 Other blanks may be analyzed as necessary following the recommendations of Chapter 2 Section 9 of the *UST Procedures Manual.*

10.4 Lab Fortified Blanks (LFB)

10.4.1 LFB is extracted using the method procedure.

10.4.2 One LFB is analyzed with each analytical batch

10.4.3 The LFB recovery requirement is 75-125% of true value.

10.4.4 If any LFB recovery fails to meet method criteria, appropriate corrective action must be taken. See 10.7, "Corrective Actions".

10.5 Matrix Spike (MS) and Matrix Spike Duplicates (MSD)

10.5.1 MS & MSD are samples that are spiked with DCS to produce a known concentration greater than the sample background concentration. Both are processed as samples.

10.5.2 MS & MSD are analyzed only when requested.

10.5.3 There are no RPD or recovery requirements for MS and MSD.

10.6 Surrogate

10.210.6.1 The surrogate should be spiked at a level to produce a recommended extract

concentration of 20 µg/mL.
10.6.2 Surrogate recoveries must be 60-120% for laboratory control samples (CCS, CVS, method blank, LFB) and 50-150 % for field samples(all other samples).
10.6.3 If any surrogate recovery fails to meet method criteria, corrective action must be taken. See 10.7, "Corrective Actions".
10.6.4 If field samples show poor surrogate recovery which is not attributable to laboratory error, DRO results must be flagged. Re-sampling, matrix spikes or other remedial action is at the discretion of the client and is not the responsibility of the laboratory.

10.7 Corrective Action
10.7.1 The actions listed below are recommended and may not apply to a particular failure.
10.7.2 Check for matrix interference or carry-over.
10.7.3 Check for errors in calculation and that concentrations of surrogates and internal standards are correct.
10.7.4 Check that instrument performance meets method criteria.
10.7.5 Re-process the data.
10.7.6 Re-analyze the extracts.
10.7.7 Extract additional aliquots of the failing sample(s) and re-analyze.
10.7.8 Collect replacement samples

11. Method Performance

11.1 Single lab method performance data for the DROs method in Ottawa sand and other soil types is presented below.

11.2 Results for diesel spikes (methylene chloride extraction direct injection, soils) using a blend of different diesel products.

23 24	Matrix	Diesel Spike Amount mg/kg	Percent Recovery
	Ottawa Sand	70	97
	Ottawa Sand	70	98
	Glacial Blue Clay	70	70
	Glacial Blue Clay	70	76
	Forest Loam	70	136
	Forest Loam	70	163
	River Sediment	70	142
	River Sediment	70	167
	Marine Sand	70	95
	Marine Sand	70	88

Notes: Analyses performed by State of Alaska, DEC Laboratory. Diesel used =A mixture made of a blend of equal weights (1:1:1) of arctic diesel, diesel #1, and diesel #2, mixed together to form a composite diesel fuel. All highly organic soil matrices showed high analyte recovery due to naturally occurring DROs.

11.3 The method detection limit for soil calculated according to 40 C.F.R..136, Appendix B (1994) was 1.6 mg/kg (external standard calibration, Ottawa sand) at SCL.

12. References

1. USEPA *Test Methods for Evaluating Solid Waste,* 3d Edition, Methods 8000,8100, 3510, 3520, 3540, 3550, and 3611.

2. "Method OA-2: Extractable Petroleum in Products", Revision January 10, 1990, University Hygienic Laboratory, Iowa City, Iowa.

3. "Method for Determination of Extractable Petroleum Hydrocarbons (EPH) in Soil and Water, Draft-February 28, 1990, prepared for Total Petroleum Hydrocarbons Method Committee by Midwest Research Institute.

4. Zilis, K., M. McDevitt, and J. Parr, "A Reliable Technique for Measuring Petroleum Hydrocarbons in the Environment," presented at the conference on Petroleum Hydrocarbons and Organic Chemicals in Groundwater, NWWA, Houston, Texas, November 1988.

5. American Petroleum Institute "Method for the Determination of DROs," Draft Revision 2February 5, 1992, prepared for Total Petroleum Hydrocarbons Method Committee.

6. "Leaking Underground Fuel Tank (LUFT) Field Manual," State Water Resources Control Board State of California, Sacramento, CA, May 1988.

7. Fitzgerald, John, "Onsite Analytical Screening of Gasoline Contaminated Media Using a Jar Headspace Procedure" in Petroleum Contaminated Soils, Vol. 2, 1989.

8. Senn, R.B., and M.S. Johnson, "Interpretation of Gas Chromatographic Data in Subsurface Hydrocarbon Investigations," Ground Water Monitoring Revie , 1987.

9. Hughes, B.M., and D.E. McKenzie, C.K. Trang, L.S.R. Minor, "Examples of the Use of an Advanced Mass Spectrometric Data Processing Environment for the Determination of Sources of Wastes" presented at 5h Annual Waste Testing and Quality Assurance Symposium, July 1989.

10. ASTM "Standard Methods for Comparison of Waterborne Petroleum Oils by Gas Chromatography," pp. 3328-78.

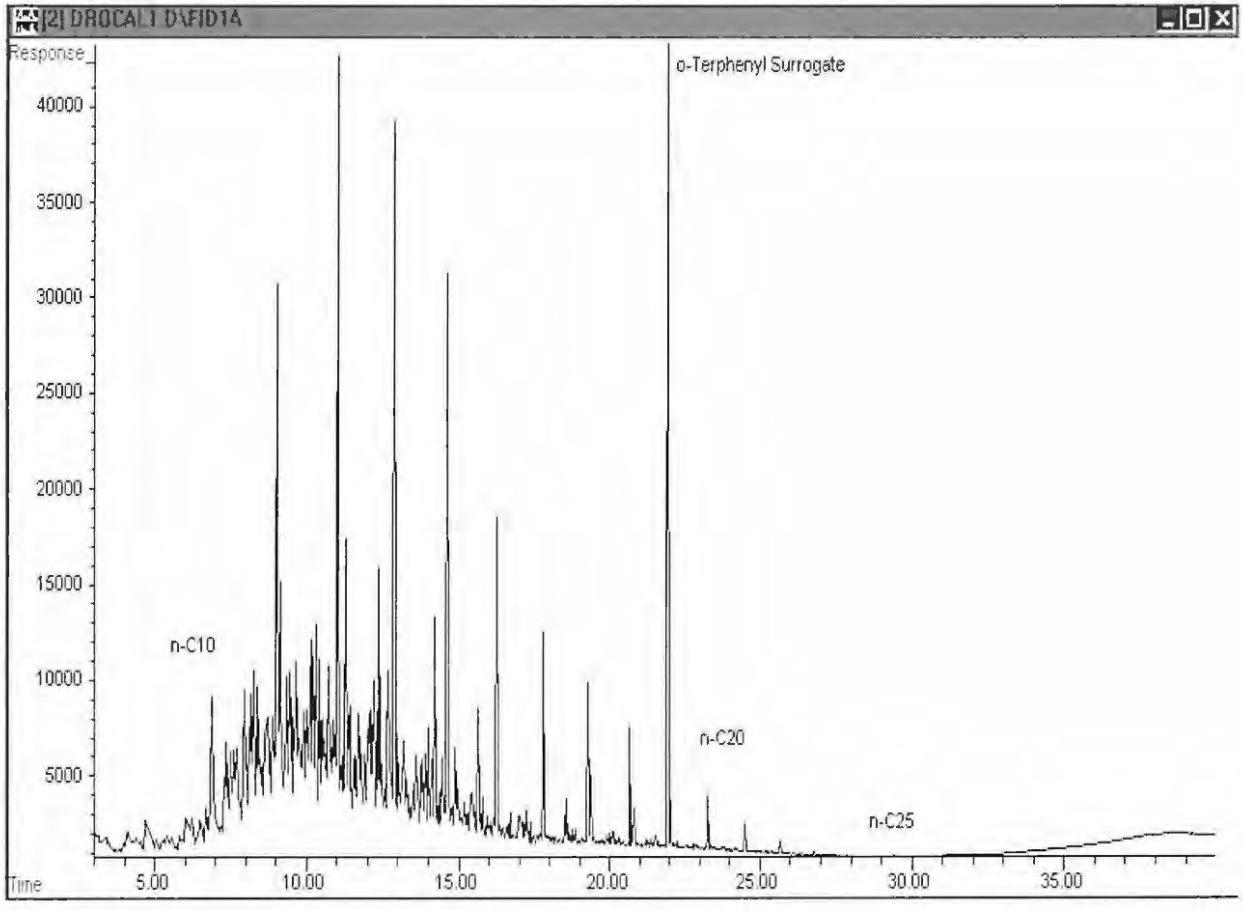
11. API consensus "Method for the Determination of Diesel Range Organics," Revision 2, 2/5/92.

12. Research done by the State of Alaska, Department of Environmental Conservation, Division of Environmental Quality, Juneau Environmental Analysis Laboratory.

13. Carrell, Robert, "Method for the Determination of Extractable Petroleum Hydrocarbons". Laboratory Advisory Board Project Oversight Group, Duwamish Brownfields/TPH Project, September 1, 1997.

14. USEPA Guidelines for Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act (40 CFR Part 136), Part VIII, July 1994.

Figure 1. Diesel Range Organics, Fuel Oil #2



Method AK102, Table 1
Acceptance Criteria for Quality Control

	Analyze Spike Concentration		Control Limits	
	Water (mg/L)	Soils (mg/Kg)	% Recovery	Relative% Difference
Lab Fortified Blanks	0.5-2.0		75-125	20
Continuing Calibration			75-125	
Calibration Verification			75-125	
Surrogate Recovery:				
Laboratory Control Sample**:	0.02	0.8	60-120	
Field Sample:	0.02	0.8	50-150	

- Suggested concentrations. May vary with matrix.
- **Laboratory Control Sample is any laboratory prepared sample used for quality control except calibration standards.

Field criteria from voluntary contribution of method performance information from Approved laboratories, and method performance at SCL.

Method AK 103

For Determination of Residual Range Organics
Version 04/08/02

1. Scope and Application

1.1 Objectives

1.1.1 This method is designed to measure the concentration of Residual Range Organics (RRO) **in soil**. This corresponds to an n-alkane range from the beginning of C_{25} to the end of C_{36}, and compounds with boiling points from approximately 400° C to 500° C. (See Figure 1 of this method.)

1.1.2 The method is primarily designed to measure lubricating or motor oils or other heavy petroleum products. Components greater than C_{36} present in products such as asphalts, and mid-range boiling point products such as diesel and bunker C, are also detectable under the conditions of the method.

1.1.3 This method can be an extension of the Method for Determination of Diesel Range Organics as specified in AK 102. All quality control requirements of both methods (Section 10 of this method) must be met. Reasonable modification to accommodate the concurrent analysis of DRO and RRO is within the scope of this method.

1.2 Quantitation Limits: The practical quantitation limit (PQL) for this method of analysis of RROs is based on studies done by laboratories other than the State of Alaska, Department of Environmental Conservation, State Chemistry Laboratory and is approximately 100 mg/kg for soils using motor oil as a standard.

1.3 Dynamic Range: Dilutions should be performed as necessary to put the chromatographic envelope within the linear range of the method. Linear range is dependent in part upon column type, detector sensitivity, and injection volume. Typically, the approximate range is 10 mg/L to 200 mg/L in extracts.

1.4 Experience: This method is based on a solvent extraction, gas chromatography (GC) procedure. This method should be used by, or under the supervision of, analysts experienced in the use of solvent extractions and gas chromatographs and skilled in interpreting gas chromatograms and their use as a quantitative tool.

2. Method Summary

2.1 This method provides gas chromatographic conditions for the detection of high molecular weight with similar characteristics and boiling points, may also be detected with this method. The sample is spiked with a surrogate compound and extracted with methylene chloride. The extract is dried and concentrated to a known volume. A portion of the dried, concentrated extract is injected into a capillary column gas chromatograph equipped with a flame ionization detector (FID), which has been temperature programmed to facilitate separation of organic compounds. Quantitation must be performed by comparing the total chromatographic area between the peak start of C_{25} and the peak end of C_{36}, both resolved and unresolved components, based on FID response, and using forced baseline-baseline integration, compared to a blended commercial standard called the Residuals Calibration Standard (see Section 3.2 of this method).

2.2 This version of the method was developed by Mary Jane Pilgrim, Ph.D. and is based in part on US EPA Methods 8000 and 8100, SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*) [1], Method OA-2 [2], the API consensus method "Method for the Determination of Petroleum Hydrocarbons", Original version, 2/3/92 [3] and work by the EPA Total Petroleum Hydrocarbons Method Committee [41, the State of Oregon, "Total Petroleum Hydrocarbon Methods" QAR 340-122-3 50 dated December 11, 1990, and the State of Washington, "Hydrocarbon Identification Method" WTPH-HCID from Guidance for Remediation of Releases from Underground Storage Tanks, Document 91-30 dated July 1991, and data from Alaska's State Chemistry Laboratory, with support from the Storage Tank Program.

3. Definitions

3.1 Residual Range Organics (RRO): All chromatographic peaks, both resolved and unresolved, eluting between the peak start of n-pentacosane (C_{25}) and the peak end of n-hextriacontane (C_{36}). Quantitation is based on direct comparison of the area within this range to the total area of the motor oil standard within the same (C_{25} - C_{36}) range as determined from FID response using baseline-baseline integration. Surrogate peak areas shall be determined by valley to valley integration.

3.2 Residuals Calibration Standard (RCS): A blend of equal weights of 30 weight and 40 weight motor oils (1:1) and diluted to appropriate concentrations in methylene chloride. This standard serves as a calibration standard for RRO. It is recommended that the RCS components be combined with the DCS components if DRO (AK102) is to be done simultaneously. If the source of the spill is known, it is suggested that the known source be used as the calibration standard.

3.3 Surrogate: n-Triacontane d62 or equivalent. A demonstration of suitability must be performed. Any variance from this surrogate must be approved by the ADEC Approval Authority.

3.4 Calibration Verification Standard (CVS): A commercial motor oil blend, prepared as in Section 3.2 of this method but with products from a source other than those used to prepare the RCS. It is used by the laboratory to verify the accuracy of the calibration. If the source of the spill is known, it can be used to verify the curve if the calibration standards are prepared from a second source. Greater than 95% of the hydrocarbons must elute between the retention time markers.

3.5 Laboratory Fortified Blank (LFB): A method blank sample spiked with diluted RCS (Section 3.2 of this methods) . The spike recovery is used to evaluate method control (see Table 1 of this method).

3.6 Retention Time Window Standard: A mixture of the normal alkanes n-pentacosane (C_{25}) and n-hexatriacontane (C_{36}) which is analyzed once every 24 hour "day" or with each batch of samples, whichever is less frequent, not to exceed 20 samples per batch. This standard serves to define the retention time window for RRO.

3.7 Internal Standard: No internal standard has been used in development of this method. Any internal standard which mimics the chemical characteristics of heavy petroleum products may be used, with prior ADEC approval.

3.8 Standard Soil: Ottawa sand or other standard soil with characteristics that match the field samples as closely as possible, used in quality control standards.

3.9 Continuing Calibration Standard (CCS): A mid-range working standard diluted from the RCS (Section 3.2 of this method), used to verify that the analytical system is operating in a manner comparable to that at the time of calibration.

3.10 Method Detection Limit (MDL): The minimum concentration of a compound that can be measured and reported with 99 percent confidence that the value is greater than zero, determined from analysis of a sample in a given matrix containing the analyte. (See 40 C.F.R. 136, Appendix B, for method of determining method detection limit.) Each laboratory must demonstrate and periodically update method detection limits for each analyte of interest.

3.11 Practical Quantification Limit (PQL): is defined as 5 times the MDL.

3.12 Method Blank – also known as a procedural blank demonstrates that apparatus and reagents used to perform the method are free from contamination

3.13 Instrument Blank – demonstrates that the instrument is free from contamination.

3.14 Solvent Blank – demonstrates that the solvent (in this case methylene chloride) used in the method is free from contamination. It should not go through the procedure. It may also serve as an instrument blank.

3.15 Other terms are as defined in SW-846 [1].

4. Interferences

4.1 Other organic compounds including, but not limited to, animal and vegetable oil and grease, chlorinated hydrocarbons, phenols, phthalate esters, and biogenic terpenes are measurable under the conditions of this method. Some lighter petroleum products such as bunker C and diesels, as well as crude oils, may produce a response within the retention time range for RRO. As defined in the method, the RRO results include these compounds.

4.2 Method interferences are reduced by washing all glassware with hot soapy water and then rinsing it with tap water, methanol, and methylene chloride. Heating the glassware to reduce contaminants should not be necessary if this cleaning method is followed. At least one blank must be analyzed with each extraction batch to demonstrate that the samples are free from method interferences.

4.3 High purity reagents must be used to minimize interference problems.

4.4 Contamination by carryover can occur whenever high-level and low-level samples are sequentially analyzed. When an unusually concentrated sample is encountered, it should be followed by a solvent blank to check for instrument contamination.

5. Safety Issues

5.1 The toxicity or carcinogenicity of each reagent in this method has not been precisely defined. However, each chemical compound should be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of Occupational Safety and Health Administration (OSHA) regulations regarding the safe handling of the chemicals specified in this method. A reference file of Material Safety Date Sheets (MSDS) should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety should be available and should be identified for use by the analyst.

5.2 A hearing protection device should be used when performing sonication.

6. Apparatus and Materials

(Unless otherwise indicated, all apparatus and materials are recommended, not required.)

6.1 Glassware

6.1.1 4-oz. amber glass wide mouth jars with Teflon-lined screw caps

6.1.2 250-mL glass centrifuge tubes (if using sonication extraction).

6.1.3 2-mL glass vials with Teflon-lined cap (autosampler vials).

6.1.4 Disposable pipettes: Pasteur.

6.1.5 Graduated cylinders: 250-mL.

6.1.6 Glass or Teflon funnels.

6.2 Boiling chips - Approximately 10/40 mesh. Heat to 400°C for 30 minutes or Soxhlet extract with methylene chloride.

6.3 Micro syringes: 1-µL, 5-µl, 10-µL, 25-µL, and 100-µL or as needed.

6.4 An analytical balance capable of accurately weighing 0.0001 g should be used for preparing standards. A top-loading balance capable of weighing to the nearest 0.01 g should be used for sample preparation.

6.5 Stainless steel spatula.

6.6 Gas Chromatography

6.6.1 Gas Chromatograph: Analytical system including appropriate gas supply and all required accessories, including a Flame Ionization Detector (FID), column supplies, gases, and syringes. A data system capable of determining peak areas using a forced baseline - baseline projection is required. A data system capable of storing and reintegrating chromatographic data is recommended.

6.6.2 Columns

6.6.2.1 Column 1: J&W DB-1 30m x 0.32 mm, 0.25 film

6.6.2.2 Alternate columns: DB-5 30m x 0.32 mm, 0.25 micron film thickness.

6.6.2.3 Other Columns may be used - capillary columns may be required to achieve the necessary resolution. The column must resolve C_{24} from C_{25} in a midrange RCS and C_{36} must be clearly identified. See Section 9.2.2 of this method for additional column performance criteria.

6.7 Sonication

6.7.1 Ultrasonic cell disrupter: A horn-type sonicator equipped with a titanium tip should be used. A Heat Systems-Ultrasonics, Inc. Model W-385 (475 watt) sonicator or equivalent (power wattage must be a minimum of 375 with pulsing capability and No. 200 ½ inch Tapped Disrupter Horn) plus No. 207 ¾ inch Tapped Disrupter Horn, and No. 419 1/8 inch Standard tapered Microtip probe.

6.7.2 A Sonabox or equivalent is recommended with the above disrupter for decreasing sound (Heat Systems-Ultrasonics, Inc., Model 432 13 or equivalent).

6.8 Soxhlet extraction apparatus as described in SW-846 Method 3540 [1].

6.9 Nitrogen evaporator with high purity (grade 4.5 or equivalent) nitrogen gas source.

7. Reagents and Standards

7.1 Reagent Water: Water that has been shown to be free from target analytes and interfering substances.

7.2 Methylene Chloride, Acetone - pesticide grade or equivalent. At a minimum, the solvents must be shown to be free from RRO.

7.3 Sodium Sulfate - (American Chemical Society (ACS) grade) granular, anhydrous. Purify by heating at 400°C for 4 hours in a shallow tray, or by extracting three times with methylene chloride and drying at 100 ±5° C. Incomplete cleaning of sodium sulfate can result in contamination.

7.4 Stock Standard Solutions - Prepare the following stock standards. Unless noted, all are prepared in the methylene chloride listed in Section 7.2 above. Standards preparation should follow guidelines in SW-846 [1]. All standards prepared by the laboratory should be stored at -10 to -20° C and protected from light. Marking of the meniscus is helpful in maintaining stock standard integrity. Standards should be checked no more than six months prior to use to assure their integrity.

7.4.1 Recommended Surrogate: 5000 µg/mL n-Triacontane-d62 (dTC). A working solution is made at 500 µg/mL (recommended concentration) in acetone.

7.4.2 Residuals Calibration Standard (RCS): A blend of equal weights of motor oil, mixed together to form a composite motor oil (1:1, 30 weight: 40 weight) is used to prepare stock calibration standards in methylene chloride. No fewer than 3 concentrations of this Residuals Calibration Standard are used for instrument calibration. A five point calibration curve is recommended. Other than one standard concentration near the practical quantitation limit, the expected range of concentrations found in project samples should define the working range of the calibration.

7.4.3 Retention Time Window Standard: A stock solution of C_{25} and C_{36} n-alkanes with each component at a level of at least 10,000 µg/mL (recommended). This blend of alkanes serves as a retention time window defining mix for RRO.

7.4.4 Stock CVS: From a blend of commercial motor oils other than those used to

prepare the RCS, make an equal weight mixture as described above (see Section 7.4.2). Prepare a stock solution of 25,000 µg/mL in methylene chloride. A working solution is made at a recommended concentration of 5,000 µg/mL in acetone.

8. Sample Collection, Preservation, Containers, and Holding Times

8.1 Soils are collected in a core tube or 4- or 8-oz amber glass jar with Teflon lined lid. The samples are stored at 4 ± 2° C from the time of collection until extraction. Extraction must be performed on soils within 14 days.[1]. All analyses of extracts must take place within 40 days.

8.2 Soil samples to be analyzed for volatiles, DRO, and RRO may be collected in the same, methanol preserved container and stored as for GRO (AK101). If this option is selected, the mechanics of the collection, preservation, and container should be discussed with the client before sampling kit preparation. RRO extraction and analysis must still meet the requirements of 8.1, above.

8.3 Performance Evaluation (PE) Samples must be obtained from a supplier approved by The NELAC Institute (TNI) or a supplier approved to ISO 17043 standards.

9. Procedure

9.1 Sample Preparation: The preferred procedure for extraction is Method 3540 (Soxhlet Extraction). However, any sample extraction technique which meets the quality assurance requirements specified in Section 10 and Table 1 of this method may be used, and the extraction solvent must be methylene chloride.

9. 1.1 Soil Preparation - Soxhlet Extraction

9. 1. 1.1 Decant any water layered on the sample. Refer to method AK 102, Section 9.1.2 if DRO is to be done simultaneously. Mix the sample well and note any foreign objects or anomalies (variable particle size, presence of oil sheen, multiple phases, etc.).

9.1.1.2 Weigh 10 g to 30 g of the original sample into an extraction thimble. Add an equal weight of anhydrous sodium sulfate and stir the mixture well with stainless steel or Teflon spatula, taking care to not rupture the thimble. The sample should have a grainy texture - if the sample clumps, add more sodium sulfate until a grainy texture is achieved and note the addition.

9.1.1.3 Place loaded thimbles in extractors and add surrogate to all samples, both field and quality control.

9.1.1.4 Prepare an LFB from the RCS and 10 g of methylene chloride rinsed standard soil. In addition, prepare a method blank.

9.1.1.5 Add 300 mL of methylene chloride to the 500-mL extraction flask. More or less extraction solvent may be used if the quality control criteria specified in Section 10 and Table 1 are met. Also add a few methylene chloride washed boiling chips to the flask. Connect the extractor to the flask and the condenser to the extractor. Allow samples to extract for 18-24 hours, or as long as necessary to achieve optimum surrogate recovery. Be sure that coolant is flowing around the condensers.

9.1.1.6 Dry the extract with anhydrous sodium sulfate (This assures that the extract is water-free before concentration.)

9.1.1.7 Concentrate extract to 1 mL at a temperature not to exceed 55 ° C or that recommended by the manufacturer of concentration apparatus being used. Transfer extracts to GC vials for analysis. Extracts should be stored in a freezer <-10° C. Record the information for extraction and concentration steps.

Note: The extraction and concentration steps must be performed under a hood. Methylene chloride is a potential health hazard (See MSDS.)

9.1.2 Moisture Determination for Solids

9.1.2.1 Moisture determinations must accompany all soils data (reported in mg/dry kg) so the client can, at will, determine the results in the original soil condition. Because of the potential for high petroleum compound concentrations in the soil, all drying should be done under a functioning hood.

9.1.2.2 To determine percentage of moisture, pre-weigh an aluminum weighing boat. Weigh 5-10 g of the sample into the boat and record both weights to the nearest 0.001 g. Dry the sample overnight in a warm (105°C) oven.

9.1.2.3 Remove the sample from the oven and cool in a desiccator until the sample reaches room temperature, and weigh to the nearest 0.01g. Record the weight.

9.1.3 Dilution Technique

9.1.3.1 This is used for product or waste samples for which extraction is not appropriate and which are soluble in methylene chloride.

9.1.3.2 Weigh 1 g of sample into a 10-mL volumetric flask. Dilute to 10 mL with methylene chloride. Transfer to a 12-mL vial with a Teflon-lined lid. Mark

meniscus and store at <4° C.

9.2 Gas Chromatography

9.2.1 Conditions (Recommended): Set helium column pressure to 20#. Set column temperature to 40° C for 2 minutes, then ramp at a rate of 120° C/min to 380° C and hold for 15 min. (run time = 49 minutes). Set FID Detector to 380° C and injector to 280° C.

9.2.2 Performance Criteria: GC run conditions and columns must be chosen to meet the following criteria:

9.2.2.1 Resolution of the methylene chloride solvent front from C_{10}, if DRO (AK 102) is to be done simultaneously.

9.2.2.2 The separation number, TZ, should be greater than 15 for C_{24} and C_{25} if DRO is to be analyzed concomitantly.

TZ = [(retention time C_{25} - retention time C_{24})/ (W ½ of C25 + W ½ of C24)] -1

Where "W ½ " = peak width at half-height

9.2.2.3 The column must be capable of separating typical motor oil components from surrogate and internal standards.

9.3 Calibration

9.3.1 Calibrate the GC, set up as in Section 9.2 of this method, with a minimum of three concentrations of RCS (five concentrations are recommended).

9.3.2 Choose Residual Calibration Standard concentrations to cover the RRO range expected in the samples, or the linear range of the instrument, whichever is less. Linearity of the calibration curve at the PQL must be documented.

9.3.3 Curve fit must be linear regression with a R2 of 0.995 or better, quadratic fit with a R2 of 0.995 or better, or if using response factors the average percent relative standard deviation (%RSD) is less than 25% over the working range.

9.3.4 The calibration curve must be confirmed using the CVS (see Section 7.4.4 of this method). This standard verifies the accuracy of the calibration. The concentration of the CVS should be within the expected concentration range of the samples to be analyzed.

9.3.5 The working response factor or calibration curve must be verified on each working day (24 hours) by the injection of a CCS (see Section 7.4.2 of this method) at a concentration mid-point on the calibration curve. The CCS is a diluted aliquot of the same standard used to initially calibrate the instrument.

9.4 Retention Time Window Definition

9.4.1 Before establishing windows, be certain that the GC system is within optimum operating conditions (see Section 9.2 of this method). Make three injections of the Retention Time Window Standard (see Section 7.4.3 of this method) and surrogate throughout the course of a 72 hour period. Serial injections over less than a 72 hour period result in retention time windows that are too tight.

9.4.2 Calculate the standard deviation of the three absolute retention times for C_{25}, C_{36}, and the surrogate.

9.4.2.1 The retention time (RT) window for individual peaks is defined as the average RT plus or minus three times the standard deviation of the absolute retention times for each component.

9.4.2.2 In those cases where the standard deviation for a particular analyte is zero, the laboratory should use ± 0.05 min. instead of the standard deviation.

9.4.3 The laboratory must calculate retention time windows for each standard on each GC column and whenever a new GC column is installed or instrument conditions changed. The data must be retained by the laboratory.

9.4.4 Retention time windows must be verified regularly and updated no less frequently than once a year.

9.5 Gas Chromatograph Analysis

9.5.1 Samples are analyzed by GC/FID. Optimum injection volumes (2 µL using the conditions established in Section 9.2 of this method) must be established for specific instrument conditions.

9.5.2 For internal standard calibration, the internal standard is spiked into each sample and standard at a specified concentration. Note: High RRO values may lead to measurement bias due to coelution with the internal standard.

9.5.3 If initial calibration (Section 9.3 of this method) has been performed, verify the calibration by analysis of a mid-point CCS (see Section 9.3.5 of this method). With each day's run, open a 24 hour analysis window. This is done by running the Retention Time Window Standard (Section 7.4.3 of this method).

9.5.4 Calculate the percent recovery of the CCS concentration. This is done for RRO as a group from the CCS. If the response factor has a percent difference greater than 25%, corrective action must be taken.

9.5.5 A solvent blank may be analyzed each day to determine the area generated on normal baseline noise under the conditions prevailing in the 24 hour period. This area is generated by projecting a horizontal baseline between the retention times observed for the peak start of C_{25} and the peak end of C_{36}. This blank is integrated over the RRO area in the same manner as for the field samples and is reported as the solvent blank (refer to Section 4 of this method). Do not baseline subtract. This information is for data interpretation purposes only.

9.5.6 Blanks should also be run after samples suspected of being highly concentrated, to prevent carryover. If the blank analysis shows contamination above the practical quantitation limit, the column must be baked out and subsequent blanks analyzed until the system is shown to retain contaminants at concentrations less than the PQL.

9.5.7 If the RRO concentration exceeds the linear range of the method (as defined by the range of the calibration curve) in the final extract, corrective action must be taken. The response of the major peaks should be kept in the upper half of the linear range of the calibration curve. Due to potential measurement bias, internal standard calibration should not be used when RRO exceeds 5000 µg/mL in the final extract. The sample should be diluted or external standard calibration should be used.

9.6 Calculations:

9.6.1 Percent Moisture Calculation

% Moisture = [(A-C)/(A-B)] x 100

Where: A = weight of boat + wet sample
B = weight of boat
C = weight of boat + dry sample

The % moisture calculation must be included in the data package.

Note: Make sure drying oven is placed under a hood. Heavily contaminated soils will produce strong organic vapors.

9.6.2 Internal Standard Calibration: The concentration of RROs in the sample must be determined by calculating the absolute weight of analyte chromatographed from a summation of peak response for all chromatographic peaks eluting between the

peak start of n-pentacosane and the peak start of n-pentetracontane, using the calibration curve or the response factor determined in Section 9.3 of this method. Also refer to Section 9.4 of this method (Retention Time Window Definition).

The concentration of RRO is calculated as follows:

Soil samples:

$$Cs = \frac{(Ax)(Cis)(D)(Vt)}{(Ais)(RF)(Vs)}$$

Where: Cs = Concentration of RROs (mg/kg).
Ax = Response for the RROs in the sample, units in area.
RF = Response Factor from CCS (see Section 9.3. 1).
Ais = Response for the internal standard, units same as for Ax.
Cis = Internal standard concentration (mg/mL).
Vt = Volume of final extract in mL.
D = Dilution factor, if dilution was performed on the sample prior to analysis if no dilution was made, D = 1, dimensionless.
Vs = Amount of sample extracted in kg.

To calculate mg/dry kg for soil samples,

$$\text{mg/dry kg RRO} = \frac{CS}{1-(\%\ \text{moisture}/100)}$$

The % moisture calculation must be included in the data package (see Section 9.1.2 of this method).

9.6.3 External Standard Calibration:

Soil samples:

$$Cs = \frac{(Ax)(A)(Vt)(D)}{(As)(Vs)}$$

Where: Cs = Concentration of RROs (mg/kg).
Ax = Response for the RROs in the sample, units in area.
As = Response for the external standard, units same as for Ax.
A = External standard concentration (mg/mL).
Vt = Volume of Final extract in mL.
D = Dilution factor, if dilution was performed on the sample prior to analysis. If no dilution was made, D = 1, dimensionless.
Vs = Amount of sample extracted in kg.

9.6.4 Some software programs are capable of performing moisture calculations with minimal analyst intervention.

10. Quality Control

10.1 Curve Verification Standard (CVS)

10.1.1 The CVS is not extracted.

10.1.2 The CVS is analyzed once with calibration standards to verify the calibration curve.

10.1.3 The CVS recovery requirement is 75-125% of true value.

10.2 Continuing Calibration Samples (CCS)

10.2.1 The CCS is not extracted.

10.2.2 The CCS is analyzed at the start and end of an analytical batch and for every 20 samples in that batch.

10.2.3 The CCS recovery requirement is 75-125% of true value.

10.3 Blanks

10.3.1 Instrument Blank may be analyzed with each analytical batch to demonstrate that the system is free from contamination.

10.3.2 Method Blank must be analyzed with each extraction batch.

10.3.3 BLANK SUBTRACTION IS NOT ALLOWED. Blanks are reported by value. This information is for data quality assessment purposes only.

10.3.4 Other blanks may be analyzed as necessary following the recommendations of Chapter 2, Section 9 of the *UST Procedures Manual.*

10.4 Lab Fortified Blanks (LFB)

10.4.1 LFB is extracted using the method procedure.

10.4.2 One LFB is analyzed with each analytical batch

10.4.3 The LFB recovery requirement is 60-120% of true value.

10.4.4 If any LFB recovery fails to meet method criteria, appropriate corrective action must be taken. See Section 10.7 of this method, "Corrective Actions".

10.5 Matrix Spike (MS) and Matrix Spike Duplicates (MSD)

10.5.1 MS & MSD are samples that are spiked with RCS to produce a known concentration greater than the sample background concentration. Both are processed as samples.

10.5.2 MS & MSD are analyzed only when requested.

10.5.3 There are no RPD or recovery requirements for MS and MSD.

10.5.4 The recovery and relative percent difference (RPD) for the MS and MSD are for informational purposes only.

10.6 Surrogate

10.6.1 Surrogate recoveries must be 60-120% for laboratory control samples (CCS, CVS, method blank, LFB) and 50-150 % for field samples (all other samples).
10.6.2 If any surrogate recovery fails to meet method criteria, corrective action must be taken. See Section 10.7 of this method, "Corrective Actions".
10.6.3 If field samples show poor surrogate recovery which is not attributable to laboratory error, RRO results must be flagged. Re-sampling, matrix spikes, or other remedial action is at the discretion of the client and is not the responsibility of the laboratory.

10.7 Corrective Action

10.7.1 The actions listed below are recommended and may not apply to a particular failure.
10.7.2 Check for matrix interference or carry-over.
10.7.3 Check for errors in calculation and that concentrations of surrogates and internal standards are correct.
10.7.4 Check that instrument performance meets method criteria.
10.7.5 Re-process the data.
10.7.6 Re-analyze the extracts.
10.7.7 Extract additional aliquots of the failing sample(s) and re-analyze.
10.7.8 Collect replacement samples.

11. Method Performance

11.1 Specific method performance data for Revision 3.0 of AK 103, Residual Range Organics, is not available at this time. Information on method performance for the C_{25} - C_{44} range (Revision 2.1) follows.

11.1.1 The method performance data presented, other than the performance evaluation samples, is based on single lab work (State of Alaska, Department of Environmental Conservation, State Chemistry Laboratory). Performance data for the RROs method in Ottawa sand and other soil types is presented below.

11.1.2 Results for motor oil spikes (methylene chloride extraction direct injection, soils) are from duplicate analyses of matrix spikes on field projects. Biases due to naturally occurring materials and existence of mixed products in the samples may exist.

Matrix	RCS Spike Amount mg/kg	Percent Recovery
Performance Samples 2001	1231	104 ± 14
1993 Composite	250	77 ± 13

(S.E. Alaska Soils)	500	107 ±15
1994 Composite	250	103 ± 10
(S.E. Alaska Soils)	500	103 ± 9
1995 Single Project	500	116 ± 9
(S. E. Alaska Soils)		

11.1.3 The method detection limit for soil calculated according to 40 C.F.R. 136, Appendix B (1994) was 51 mg/kg (external standard calibration).

12. References

1. USEPA, *Test Methods for Evaluating Solid Waste,* 3d Edition; Methods 8000, 8100, 3510, 3520, 3540, 3611 and 3550.

2. "Method OA-2: Extractable Petroleum in Products", Revision January 10, 1990, University Hygienic Laboratory, Iowa City, Iowa.

3. "Method for Determination of Extractable Petroleum Hydrocarbons (EPH) in Soil and Water, Draft-February 28, 1990, prepared for Total Petroleum Hydrocarbons Method Committee by Midwest Research Institute.

4. Zilis, K., M. McDevitt, and J. Parr, "A Reliable Technique for Measuring Petroleum Hydrocarbons in the Environment", presented at the conference on Petroleum Hydrocarbons and Organic Chemicals in Groundwater, NWWA, Houston, Texas, November 1988.

5. American Petroleum Institute "Method for the Determination of Diesel Range Organics", Draft Revision 2-February 5, 1992, prepared for Total Petroleum Hydrocarbons Method Committee.

6. "Leaking Underground Fuel Tank (LUFT) Field Manual", State Water Resources Control Board, State of California, Sacramento, CA, May 1988.

7. Fitzgerald, John, "Onsite Analytical Screening of Gasoline Contaminated Media Using a Jar Headspace Procedure" in Petroleum Contaminated Soils, Vol. 2, 1989.

8. Senn, R.B., and M.S. Johnson, "Interpretation of Gas Chromatographic Data in Subsurface Hydrocarbon Investigations" Ground Water Monitoring Review , 1987.

9. Hughes, B.M., and D.E. McKenzie, C.K. Trang, L.S.R. Minor, "Examples of the Use of an Advanced Mass Spectrometric Data Processing Environment for the Determination of Sources of Wastes" presented at 5th Annual Waste Testing and Quality Assurance Symposium, July 1989.

10. American Petroleum Institute, "Method for Determination of Petroleum Hydrocarbons", Draft Revision, Original, 3 February 1992, prepared for the Total Petroleum Hydrocarbons Methods Committee.

11. State of Washington, Department of Ecology, "Total Petroleum Hydrocarbons Analytical Method WTPH-HCID."

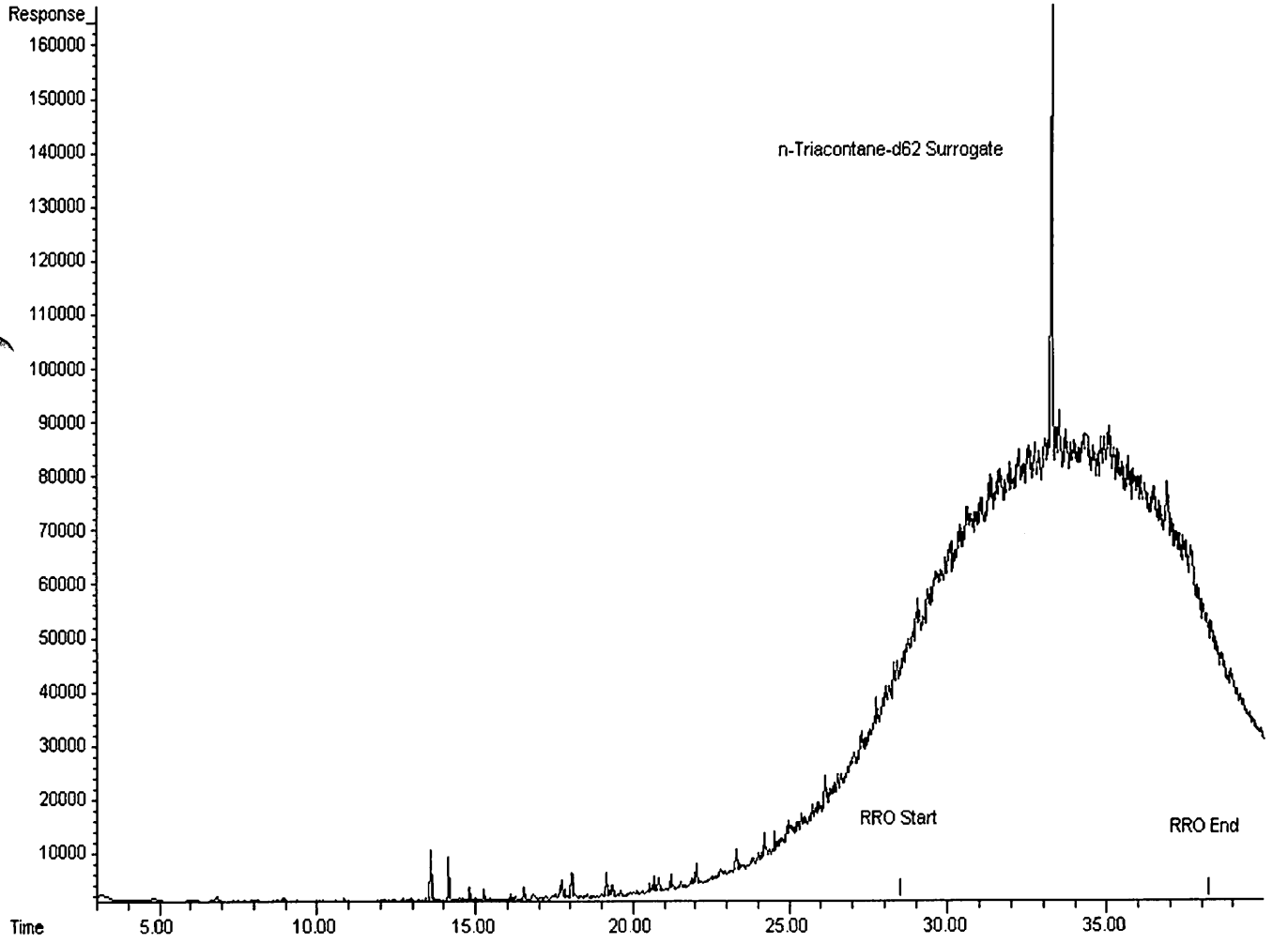
12. Research done by the State of Alaska, Department of Environmental Conservation, Division of Environmental Quality, State Chemistry Laboratory.

13. Carrell, Robert, "Method for the Determination of Extractable Petroleum Hydrocarbons", Laboratory Advisory Board Project Oversight Group, Duwamish Brownfields/TPI-I Project, September 1, 1997.

14. USEPA "Guidelines for Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act" (40 C.F.R. 136, Part VIII, July 1994).

Figure 1. Residual Range Organics at 25 mg/mL, or 25,000,000 ug/L

Chromatogram is based on 25mg/mL of RRO standard made from 1:1 mixture of Valvoline 30 wt and Valvoline 40 wt motor oil.100 ug/mL of n-Triacontane-d62 surrogate. GC conditions: HP 5890 series II GC/FID, HP-5 column 30m x 0.32mm x 0.25um, H2 carrier gas, Merlin high pressure microseal septum, Injector temperature - 320°C, Detector temperature - 330°C Oven temperature program - 45°C for 3 minutes, 8°C/minute to 320°C hold for 2.63 minutes for total run time of 40 minutes.



Method AK 103, Table 1
ACCEPTANCE CRITERIA FOR QUALITY CONTROL

ANALYTE	SPIKE CONCENTRATION	CONTROL LIMITS	
	Soil (mg/kg)	% Recovery	Relative % Difference
Lab Fortified Blank			
Residual Range Organics	500 mg/kg	60-120	20
CVS/CCS			
Residual Range Organics	2000 mg/L	75-125	
Surrogate Control Samples			
n-Triacontane-d62	50 mg/kg	60-120	
Surrogate Recovery (field samples)			
n-Triacontane-d62	50 mg/kg	50-150	

APPENDIX D

Alaska Series Laboratory Methods for the Analysis of Aliphatic and Aromatic Gasoline Range Organics (AK101AA), Aliphatic and Aromatic Diesel Range Organics (AK102AA), and Aliphatic and Aromatic Residual Range Organics (AK103AA)

Forward for AK Methods 101AA, 102AA, 103AA

The Alaska Department of Environmental Conservation (ADEC) has published these laboratory methods to provide ADEC-approved laboratory test methods and related information for laboratory analysts, data users, and other interested parties.

In order to obtain approval for the AK Series "AA" Methods, AK101AA,AK102AA, AK 103AA, laboratories must pass a performance evaluation audit for each method as outlined in the Underground Storage Tank Regulations, 18 AAC 78.800-815. Guidelines for the performance evaluation sampling for these methods are outlined below.

1) One sample for each hydrocarbon range (GRO, DRO, RRO) and above the reporting limit for both aromatic and aliphatic compounds and below 500X the reporting limit shall be analyzed for each reporting matrix within the ADEC defined time period. The aromatics should be fortified in the mixtures such that they are no less than 40% of the total hydrocarbon to ensure the ability to detect them in low concentration samples.
2) All volatiles samples can be mixed using methanol.
3) Soil semivolatile standards should be relatively simple. The sample concentrates can be made up in hexane or methylene chloride. ADEC suggests hexane for the semivolatile samples as it will be easier to quantitatively transfer without losses due to evaporation.
4) Semivolatile water standards require a concentrate that can be mixed with water and will not adversely affect the SiO_2 or Al_2O_3 partitioning. ADEC experience has shown small amounts of methanol or acetone cause significant breakthrough on the columns. To attempt to alleviate the concern of using a non-miscible solvent, we suggest the following possibilities. Of these options the first two are the most desirable.
   a) Create concentrates in water. Make up 50 or 100mL water concentrates and require the labs to quantitatively measure 40 or 80mL of water standard into a liter of "clean" water. This has been relatively easy for the lower concentrations, but the higher pose a slight problem.
   b) Send full 1L samples to each lab. It is the same as the labs are used to seeing from their clients. Preservatives may be necessary.
   c) Create concentrates in hexane. Hexane rather than methylene chloride will be better since it does not drop to the bottom of a continuous extractor. It would have to be extracted both from the top of the water and in the water allowing some equilibrium to be established. Either way, if a shakeout is used, an equilibrium is established during the process of shaking the sample.
5) Results required for these Performance Evaluation samples include:
   a) standard deviation;
   b) two and three sigma limits;
   c) true values; and
   d) percent recoveries.

Method AK101AA

Method for the Determination of Aromatic and Aliphatic Hydrocarbons in Gasoline Range Organics
Version 3-1-99

1 Scope & Application

1.1 This method is used for the extraction, fractionation, and quantification of aromatic and aliphatic compounds in the gasoline range. Adopted methodology by the Alaska Department of Environmental Conservation (ADEC) has established guidelines defining gasoline range organics (GRO), diesel range organics (DRO), and residual range organics (RRO) for gross organic measurements by Gas Chromatography. The intention of this method is to use these existing criteria and provide guidance for the fractionation of aromatic and aliphatic compounds within the gasoline range.

1.2 This, and most other volatiles aliphatic aromatic, fractionation methods are based on the EPA SW-846 Method 8015 & 8020 and related techniques employed throughout the petroleum industry.

1.3 This method provides guidance for laboratories interested in performing aromatic and aliphatic fractionation. It also defines general quality control guidelines and control limits to be used until statistical data is available.

1.4 This method is designed for the fractionation of aromatic / aliphatic compounds in the gasoline range. This has been defined as the beginning of C_6 to the beginning of C_{10}. This range includes gasolines of various types, naphthas, etc.

1.5 It is important to note fuels are crude oil distillates. This method is designed to accurately measure aliphatic compounds that fall only between the listed n-alkane hydrocarbon markers and specific C_6 to C_9 benzene and aykyl benzenes. Because distillates are complex mixtures of hydrocarbons, they may extend beyond the ranges defined by the ADEC.

1.6 This is a performance-based method. On October 6, 1997, EPA published guidelines for performance-based methodology -- 62 FR 52098. The intention is to encourage method development within the laboratory community that will 1) decrease costs of analysis, 2) increase analytical precision and accuracy, 3) allow laboratories to better fit methods to data quality objectives.

1.7 Being a performance-based method, heavy reliance on performance evaluation samples will be required. Laboratories shall request, analyze, and submit performance evaluation samples on a periodic basis to retain ADEC approval.

1.8 This is meant to be a guidance document; it shall not take the place of an individual laboratory Standard Operating Procedure or training program. Each laboratory shall maintain a Standard Operating Procedure that thoroughly describes the method, techniques employed, and verification of method performance. The laboratory shall, also, maintain training records for analysts who perform tasks related to this method. Major variances from this method shall be disclosed on data report forms.

2 Summary of Method

2.1 While several techniques are available for aromatic and aliphatic fractionation analysis that may produce the desired results, the method listed has been found preferable.

2.2 The quantification of gasoline range aromatic and gasoline range aliphatic hydrocarbons are described.

2.3 A soil, water, or sludge sample is appropriately diluted, extracted (if a soil) with methanol, and analyzed by gas chromatography. The gas chromatograph (GC) must be equipped with a dynamic headspace concentrator, e.g. a purge and trap device, and detection system capable of detecting both aromatic and aliphatic hydrocarbons, a Photoionization Detector (PID) and Flame Ionization Detector (FID) in series is recommended.

2.4 Compounds measured using the FID or other "carbon counter" style detector, when used for fuels analysis, may be quantified as a total area as traditionally done by method AK101. Analytes measured by PID or similar detector preferential for aromatic hydrocarbons must be individually identified and quantified.

2.5 This method relies on the fact that the only aromatic compounds that elute between C_6 and C_9 on a typical volatiles chromatographic column are the compounds commonly referred to as BTEX. Most of the remaining C_9 aromatics elute between the C_9 and C_{10} alkane markers; two, however, do not, but shall be included in this analysis.

2.6 This method has been demonstrated to reduce many of the problems associated with using the PID/FID detector combination for gasoline range aromatics/aliphatics fractionation. It reduces the error caused by analyzing a transitional hydrocarbon (e.g. arctic diesel or jet fuel) or an aged gasoline using the volatiles method. Often, one can not tell the difference between a highly degraded gasoline where high levels of aromatics exist and the light ends of a light diesel range distillate. Using the patterns of the C_9 alkyl benzenes, one has the tools to assist in making this determination.

Hydrocarbon compounds that elute between C_9 and C_{10} are difficult to analyze. Previous methods have used the gross difference between the amount of analyte reported by the FID and the PID to determine aromatic and aliphatic hydrocarbons present. The PID is not sufficiently selective for larger molecules and does not adequately report gross aromatic values in this range. Further, unsaturated gasoline range compounds (olefins) will also cause false positive results on the PID.

This method quantifies C_6, C_7, C_8, and C_9 alkyl benzenes as aromatics. No aromatic compounds which elute earlier than these are observed, hence, identification of these compounds provide a high degree of confidence in quantification of aromatic compounds.

3 Definitions

3.1 Gasoline Range Organics - Organic compounds which elute by gas chromatography between the beginning of n-C_6 and the beginning of n-C_{10}.

3.2 Diesel Range Organics - Organic compounds which elute by gas chromatography between the beginning of n-C_{10} and the beginning of n-C_{25}.

3.3 Residual Range Organics - Organic compounds which elute by gas chromatography between the beginning of n-C_{25} and the end of n-C_{36}.

3.4 Instrument Blank - A clean solvent analyzed to demonstrate the cleanliness of the analytical system.

3.5 Analytical Batch - A set of samples, not to exceed 20, which are extracted, concentrated, and fractionated together. Each analytical batch shall consist of 20 or fewer samples, a method blank, two laboratory control samples, and a matrix spike.

3.6 Method Blank - A sample of clean sand or clean water that is spiked with surrogate compounds and extracted and fractionated along with the analytical batch of samples.

3.7 Retention Time Marker - A standard used to demonstrate the integration ranges for GRO, DRO, and RRO.

3.8 Initial Calibration - A set of standards used to define the concentration calibration range of the gas chromatograph. The concentration of the lowest standard must be between 3 and 5 times the method detection limit for this analysis. The initial calibration mixture is a mixture of several compounds within the proper range. These compounds shall span the entire GRO, DRO, or RRO ranges.

3.9 Calibration Verification - A standard, independent of the initial calibration mixture, used to verify the accuracy of the initial calibration. For this method it is common to use a gasoline.

3.10 Continuing Calibration - A mid-range calibration standard used to verify the initial calibration while analyzing samples. A continuing calibration standard shall be analyzed with every 10 analytical injections on the gas chromatograph and at the end of an analytical run even if fewer than 10 samples were analyzed since the previous continuing calibration.

3.11 Surrogate Standard Compounds - Compounds not typically present in GRO, DRO, or RRO hydrocarbons, which are placed in known quantities in each sample, method blank, laboratory control sample, and matrix spike to determine the recovery and accuracy of the analysis. The surrogate mixture shall contain, at a minimum, one aromatic compound and one aliphatic compound. A secondary use of the surrogate standard is to demonstrate the effectiveness of the fractionation. Control limits shall be placed on the amount of surrogate breakthrough observed in each sample, method blank, laboratory control sample, and matrix spike.

3.12 Matrix Spiking / Laboratory Control Compounds - A combination of aromatic

and aliphatic compounds added to laboratory control samples and matrix spikes to demonstrate laboratory precision and accuracy.

3.13 Aromatic Compounds - Hydrocarbon compounds which are related to benzene.

3.14 Aliphatic Compounds - Paraffins, olefins, branched paraffins, and cyclic paraffins. These compounds have no or few carbon - carbon double bonds and make up the majority of fuels

3.15 Polar Compounds - Typically associated with biomass. In the terms of this method, they are considered undesirable compounds and are removed if proper corrective action techniques are used.

3.16 Method Detection Limit (MDL) – The minimum concentration of a compound that can be measured and reported with 99 percent confidence that the value is greater than zero, determined from analysis of a sample in a given matrix containing the analyte. (See 40 C.F.R. 136, Appendix B, for method of determining method detection limit. Each laboratory must demonstrate and periodically maintain method detection limits for each analyte of interest. A method detection limit is a statistical quantity defined as the point where one has a 99% confidence they are not seeing either a false positive or a false negative. Near the MDL the confidence in quantification is very low.)

3.17 Quantification Limit - Practical quantitation limit (PQL) is a certain point where one has a 95% confidence in the quantification of a substance. Practical quantitation limits (PQL) for this method for analysis of GRO must not exceed 20 mg/kg for soils and 20 µg/L for waters.

3.18 Laboratory Control Sample and Laboratory Control Sample Duplicate (LCS/LCSD) - These samples are used by the laboratory to demonstrate a method's precision and accuracy. These are samples identical to a method blank with the exception they are spiked with a known amount of analyte. They are taken through the entire extraction and analytical process.

3.19 Matrix Spike - An actual sample that is spiked with a known amount of analyte. This sample can give valuable information about the behavior of analytes in this sample and may be extrapolated to other samples from the same area.

4 Interferences

4.1 Solvents, reagents, glassware, and other sample processing hardware may yield discrete artifacts and/or elevated baselines causing misinterpretation of gas chromatograms. All of these materials must be demonstrated to be free from interference under the conditions of the analysis, by analyzing reagent and method blanks.

4.2 High purity reagents must be used to minimize interference problems.

4.3 Washing all glassware with hot soapy water and then rinsing with warm tap water and methanol reduces method interferences.

4.4 Contamination by carryover can occur whenever high-level and low-level samples are sequentially analyzed. Whenever an unusually concentrated sample is analyzed, it

must be followed by the analysis of a system blank to check for cross-contamination.

4.5 Matrix interferences may be caused by contaminants that are co-extracted from the sample. The extent of matrix interference will vary considerably from one source to another depending upon the nature and diversity of the site being sampled.

4.6 Chromatographic columns typically "bleed" stationary phase material at high temperatures. Typically, the use of a column compensation program by the gas chromatograph will yield satisfactory results.

4.7 Many compounds elute along with the C_8 and C_9 alkyl benzenes. Chromatography should be adequate to determine these compounds from aliphatic compounds. Interpretation should be supervised and reviewed by experienced chemists.

5 Health and Safety

The toxicity and carcinogenic nature of each reagent used in this method has not been precisely defined. Each chemical compound should be treated as a potential health hazard. Exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current safety program to minimize exposure and potential hazards from personnel. A reference file of material safety data sheets (MSDS) shall be made available to all personnel.

6 Apparatus and Materials

6.1 Equipment

6.1.1 Gas Chromatograph (GC): An analytical system with temperature programmable gas chromatograph for use with capillary columns is required. The data system must be capable of storing and reintegrating chromatographic data and must be capable of determining peak areas using a forced baseline projection.

6.1.2 Recommended chromatographic column: A J&W DB-5MS 30m x 0.32mm ID x 1.0µm stationary phase has been successfully used. Any moderately polar column may be used (listed below is a sample of stationary phases evaluated). The choice of column must be demonstrated to be capable of separating gasoline range compounds and eluting the aromatic compounds listed in Section 6.4.2 of this method with minimal column bleed.

DB-5
Hp-5
DB-VRX

6.1.3 A dynamic headspace apparatus capable of purging a sample with an inert gas and trapping analytes on a solid packing, then heating the trap and eluting the analytes into the gas chromatograph.

6.1.5 Analytical balances:

6.1.5.1 An analytical balance capable of measuring 0.0001g is required for standards preparation.

6.1.5.2 An analytical balance capable of measuring 0.01g is required for measuring sample weights.

6.1.6 Drying oven: an oven capable of maintaining 150°C is used for drying of glassware and syringes.

6.2 Glassware

6.2.1 20 & 40mL VOA vials.

6.2.2 Syringes - 10, 25, 100, 500, 1000, 5000, and 10,000µL.

6.3 Reagents

6.3.1 Methanol – purge and trap grade or better, must be demonstrated to be below method detection limits for gasoline range contaminants.

6.3.2 Ottawa sand - cleaned beach sand used for soil method blanks.

6.4 Standards

6.4.1 Retention time marker - shall consist of a minimum of n-C_6 and n-C_{10}. More n-alkanes are recommended. This mixture is typically injected into the GC at a concentration of 50µg/mL for each compound.

6.4.2 Initial calibration mixtures - The use of a FID or other "carbon counting" detector for hydrocarbons allows a free association between hydrocarbon compounds providing little or no injector discrimination is present, hence, the gasoline standards commonly used in association with AK101 are adequate. Aromatic compounds must be individually calibrated on the PID.

For PID: Calibrate for the following on an individual basis:

Benzene
Toluene
Ethylbenzene
o-, m-, & p-xylenes
1,2,3-Trimethylbenzene
1,3,5-Trimethylbenzene
1,2,4-Trimethylbenzene
1-ethyl-2-methylbenzene
1-ethyl-3-methylbenzene

1-ethyl-4-methylbenzene
n-propylbenzene
Isopropylbenzene

A minimum of five dilutions of this mixture must be used for calibration purposes. The lowest concentration standard shall be within a factor of three to five of the method detection limit or at the reporting limit, whichever is lower. The highest concentration shall define the upper limit to the calibration. Sample extracts that contain concentrations higher than the calibration curve shall be diluted and reanalyzed.

6.4.3 Calibration verification mixture – Use similar standards as were used for initial calibration, but originate from a separate source.

6.4.4 Continuing calibration mixture - A mid-level standard using the same or similar compounds used in the initial calibration mixture should be prepared for this purpose. The calibration verification mixture may be used.

6.4.5 Surrogate standard mixture - A surrogate mixture shall be made in methanol. Working standards should be prepared to yield a concentration of 100µg/mL of the proper surrogate in each of the final fractions. A minimum of two surrogate compounds must be spiked into each sample, method blank, LCS/LCSD, and matrix spike. Bromofluorobenzene and ααα-trifluorotoluene have been successfully used for this purpose.

6.4.6 Internal standard mixture (optional) – Fluorobenzene or another compound may be used as an optional internal standard if deemed necessary by the analyst.

6.4.7 Laboratory control sample / matrix spike mixture - A mixture of aromatic and aliphatic compounds -- a minimum of three each -- shall be used as a laboratory control sample / matrix spike mixture. The mixture shall contain both aromatic and aliphatic compounds and have a concentration sufficient such that a final concentration in each extract fraction is 50µg/mL of each component. For example, if five aromatics and five aliphatics are used then the final concentration of each fraction should be 250µg/mL.

7 Sample Collection, Preservation, and Handling

7.1 Aqueous samples are collected in 40mL glass bottles with Teflon-lined screw caps known as VOA vials.

7.2 Soil and sediment samples are collected in 4 oz. (120 mL) amber wide-mouth glass jars with Teflon-lined septum screw caps. They should be approximately 25g and have added an aliquot of methanol preservative consisting of methanol spiked with one of the above surrogates.

7.3 Aqueous samples must be preserved at the time of sampling by the addition of a suitable acid to reduce the pH of the sample to less than 2.0. This may be accomplished

by the addition of a few drops of 1:1 HCl to a 40mL sample. The use of alternative acids is permissible. Following collection and addition of acid, the sample must be cooled to 4°C.

7.4 A chain of custody form must accompany all aqueous, soil, and sediment samples, documenting the time and date of sampling and any preservative additions.

7.5 Aqueous samples must be analyzed within 14 days of collection.

7.6 Soil and sediment samples must be analyzed within 28 days of collection.

8 Procedure

8.1 Sample Preparation – Samples or sample extracts are measured into a 5mL syringe, adjusted to 5.0mL, and added to the sample chamber of a purge and trap apparatus.

8.1.1 Water analysis

8.1.1.1 If analyst does not deem dilution necessary, pour water sample into the plunger portion of a 5mL volumetric syringe and adjust to 5.0mL.

8.1.1.2 Add surrogate standard solution through the open end of the syringe.

8.1.1.3 Place sample in sample chamber of the purge and trap.

8.1.2 Soil analysis

8.1.2.1 Allow field sample to equilibrate for 48 hours.

8.1.2.2 Fill and adjust a 5mL syringe with water. If sample does not require dilution, place up to 250µL of methanol extract into clean water and add lab surrogate/internal standard solution.

8.1.2.3 Place in purge and trap sampling apparatus.

8.2 Quantification

8.2.1 Analyze sample in the same manner as typical AK101 / EPA8021B samples.

8.2.2 Calibrate the instrument using standards listed above.

8.2.3 Quantify the individual aromatic compounds and sum their concentrations. This is the gasoline range aromatic result.

8.2.4 Quantify the "total GRO" as described by AK101.

8.2.5 Subtract the aromatic result from the total GRO result to obtain the aliphatic result.

Note this result consists of non-aromatic compounds and may include aliphatics (or paraffins), cyclic paraffins, olefins, ketones, aldehydes, etc.

8.3 Analytical

8.3.1 Gas Chromatograph Conditions (Recommended)

Parameter	Setting
Gas	Helium
Linear velocity	60 - 65cm/s
Initial Temp.	35°C
Initial Time	4min.
Rate	8°C/min.
Final Temp.	250°C
Hold	5 - 10min.
Injector Temp.	250°C
Detector Temp.	255°C

8.3.2 Gas Chromatograph Sequencing - A typical GC sequence must include a 24 hour retention time marker, a continuing calibration standard for every 10 injections -- that is, a beginning CC, and one after each subsequent 10 injections -- and an ending continuing calibration standard. Each sample batch should be analyzed in one sequence on the same instrument.

8.3.3 Calibration - A minimum of 5 concentrations of standard must be used to define the calibration curve. The concentration of each standard is the total of the concentrations of analytes present in that standard, hence, 5 analytes at 50µg/mL has a total concentration of 250µg/mL.

8.3.3.1 The lowest standard shall be equivalent to the reporting limit or a value three to five times the method detection limit, whichever is lower.

8.3.3.2 The highest concentration standard shall define the highest extract concentration that may be reported without dilution.

8.3.3.3 Whenever possible, use a least squares linear regression for calibration. Quadratic curves and average of response factors are acceptable provided adequate quality control and performance parameters are consistently met.

9 Calculations

9.1 Response Factors

Eq. 1

Where

$A_{x,std}$ = Area of analyte in standard.
$C_{x,std}$ = Concentration of analyte in Standard in µg/mL.

9.2 Concentrations

9.2.1 Soil External Standard (example) – many software packages will report concentrations of extracts without any problem. The following is for those cases where this is not done. It requires an average of response factors.

$$Concentration\ in\ Soil(mg/Kg) = \frac{(Area_x)(df)(V_f)(1000\mu g/mg)}{(rf)(m_f)(W_t)}$$ Eq. 2

Where

A_x = Area of analyte in extract.
df = Dilution Factor of extract.
V_f = Final volume of extract after concentration step.
rf = Response factor.
m_f = Fractional dry mass (% Dryness)
W_t = Initial Weight of soil sample.

Note: If instrument reports concentration in extract; that value can replace the ($Area_x$/rf) portion of the equation.

9.2.2 Water External Standard (example) – many software packages will report concentrations of extracts without any problem. The following is for those cases where this is not done. It requires an average of response factors.

$$Concentration\ in\ Water(\mu g/L) = \frac{(Area_x)(df)(V_f)}{(rf)(V_i)} \qquad \text{Eq. 3}$$

Where

A_x =	Area of analyte in extract.
df =	Dilution Factor of extract.
V_f =	Final volume of extract after concentration step.
rf =	Response factor.
V_i =	Initial volume of water (aqueous) sample.

Note: If instrument reports concentration in extract; that value can replace the ($Area_x$/rf) portion of the equation.

9.3 Fractional Mass of a soil – This is the fractional version of %Dryness for use in soil calculations.

$$Fractional\ Mass = \frac{(m_d)}{(m_s)} \qquad \text{Eq. 4}$$

Where

m_d =	Weight of dried soil.
m_s =	Weight of sample before drying.

9.4 Relative Percent Difference (RPD)

$$RPD = \frac{(X_1 - X_2)}{(X_1 + X_2)/2} * 100\% \qquad \text{Eq. 5}$$

10 Quality Control

10.1 Retention Time Markers

10.1.1 A retention time marker must be analyzed at least once every 24-hour period or once each day of instrument operation.

10.1.2 The analyst must combine use of the retention times for the ranges of interest from three separate retention time markers to determine acceptable retention time variation.

10.1.3 The retention time window for the beginnings and ends of the hydrocarbon ranges must be calculated as follows from the beginning of C_6 to the end of C_{10}.

10.1.4 If the retention time of a retention time marker standard falls outside the established window, the retention time must be updated and a new retention time window established.

10.2 Initial Calibration – A minimum five-point calibration must be performed to establish the working range of the Gas Chromatograph.

10.2.1 An initial calibration must be made up for each fraction – aromatic and total gasoline range hydrocarbons.

10.2.2 The lowest concentration must be between 3 and 5 times the method detection limit concentration or at the reporting limit concentration, whichever is lower.

10.2.3 The highest concentration will define the upper limit concentration that may be reported without extract dilution.

10.2.4 If a linear regression is used (recommended) the coefficient of correlation must be 0.98 or higher.

10.2.5 If an average of response factors is used the maximum %RSD must be no greater than 15%.

10.2.6 A quadratic calibration may be used if the GC software allows this type of calibration. The coefficient of correlation must not fall below 0.98.

10.2.7 All data points in the calibration should be weighted equally.

10.2.8 Corrective Actions

a) If the initial calibration is outside the control limits, analysis shall not be performed.
b) Reintegrate all standards.
c) Prepare and reanalyze a new curve.

10.3 Second Source Calibration Verification – A standard used to verify the initial calibration.

10.3.1 The second source calibration verification may be made up from a standard similar to the initial calibration at an intermediate level.

10.3.2 The second source compounds must be obtained from a separate source other than the initial calibration compounds.

10.3.3 The second source calibration verification standard may also be used as the continuing calibration standard.

10.3.4 The recovery of the second source calibration verification must be +/- 15% of the true value.

10.3.5 Corrective Actions

a) If the second source verification standard is outside the control limits analysis shall not be performed.
b) Reanalyze the second source calibration verification standard.
c) Prepare a new standard.
d) Prepare and analyze a new initial calibration.

10.4 Instrument Blank

10.4.1 Must be below reporting limits before proceeding with further analysis.

10.4.2 Must be analyzed at least once every 24 hours of instrument operation.

10.4.3 An instrument blank is recommended after samples high in concentration.

10.4.4 Corrective Actions

a) If an instrument blank is outside the limits, all samples associated with that blank must be reanalyzed.

10.5 Continuing Calibration Standard

10.5.1 The Continuing Calibration Standard may be made up from a standard similar to the initial calibration at an intermediate level.

10.5.2 The continuing calibration standard may also be used as the second source calibration verification.

10.5.3 The recovery of the second source calibration verification must be +/- 15% of the true value.

10.5.4 A continuing calibration standard must be analyzed at the beginning of an

analytical run, once every 10 injections on the GC, and at the close of the run.

10.5.5 Corrective Actions

(a) If a CCV is outside the limits, all samples associated with that standard must be reanalyzed.
(b) Be certain CCV is fresh and within limits.

10.6 Method Blank

10.6.1 The method blank must be made up from a matrix similar to the samples within the analytical batch (e.g. water for aqueous, sand for sandy soil, clean loam for mossy high biomass samples)

10.6.2 Surrogate standards must be added to all method blanks and must fall within the window of 70 – 120% of the true values.

10.6.3 The method blank must be free of contamination (below reporting limits) within the specified range.

10.6.4 Corrective actions

a) **Reanalyze method blank being sure no instrument carryover is present.**
b) **If a problem persists, or surrogates are outside acceptable ranges, associated analytical batch must be re-extracted and analyzed.**

10.7 Laboratory Control Sample and Laboratory Control Sample Duplicate (LCS/LCSD).

10.7.1 The LCS/LCSD/Matrix Spike working standard must be made up of a synthetic mixture of analytes. A minimum of three aromatic and three aliphatic compounds must be used for each range (DRO, RRO, GRO).

10.7.2 The LCS/LCSD should be made up from a matrix similar to the samples within the analytical batch (e.g. water for aqueous, sand for sandy soil, clean loam for mossy high biomass samples)

10.7.3 Surrogate standards must be added to all LCS/LCSD and must fall within the window of 70 – 120% of the true values.

10.7.4 Matrix spike/LCS compounds must be added to all LCS/LCSD samples and must fall within the window of 70 – 120% of the true values.

10.7.5 The duplicate must have a relative percent difference of less than 20%.

10.7.6 Corrective actions

a) **Reanalyze LCS/LCSD being sure no instrument carryover is present.**
b) **If problem persists, or surrogates are outside acceptable ranges, associated analytical batch must be re-extracted, re-fractionated, and/or re-analyzed.**

10.8 Matrix Spike

10.8.1 The LCS/LCSD/Matrix Spike working standard should be made up of a synthetic mixture of analytes. A minimum of three aromatic and three aliphatic compounds must be used for each range (DRO, RRO, and GRO) and the true values of each must be documented.

10.8.2 The matrix spike must be made up from a sample within the analytical batch.

10.8.3 Surrogate standards must be added to all matrix spike samples and should fall within the window of 50 - 150% of the true values.

10.8.4 Matrix spike/LCS compounds must be added to all matrix spike samples and should fall within the window of 50 - 150% of the true values

10.8.5 Corrective actions: No corrective actions are required for a matrix spike that is out of compliance.

10.9 Surrogate Spikes

10.9.1 At least two surrogate compounds which do not co-elute or otherwise interfere with the analytes of interest must be added to each sample, method blank, LCS/LCSD, and matrix spike.

10.9.2 The recovery of surrogate standards must not be outside the range 70 – 120% for method blanks and LCS/LCSD samples.

10.9.3 The recovery of surrogate standards should not be outside the range 50 - 150% for all remaining samples and matrix spikes.

10.9.4 Corrective Actions

a) **If the surrogates for a sample are out of limits, then that sample must be re-analyzed.**
b) **If a surrogate is out of limits in the same direction (e.g. low both times) for a second time, then the report shall reflect a matrix effect.**
c) **If a surrogate compound is out of limits for a method blank or LCS/LCSD sample, then that sample must first be re-analyzed. If it is still out, the entire analytical batch must be re-extracted, re-fractionated, and re-analyzed.**

11 References

11.1 Alaska Department of Environmental Conservation, Methods AK101.

11.2 The Federal Register, 62 FR 52098, Oct 1997.

11.3 Massachusetts Department of Environmental Protection and ABB Environmental Services, Inc., Wakefield, MA "Interim Petroleum Policy: Development of Health-based Alternative to the Total Petroleum Hydrocarbon (TPH) Parameter", August 1994.

11.4 USEPA, "Measurement of Petroleum Hydrocarbons: Report on Activities to Develop a Manual" Prepared by Midwest Research Institute, Falls Church, VA, under EPA Contract #68-WO-0015, WA No. 4; submitted to USEPA Office of Underground Storage Tanks, Washington, DC; November 20, 1990.

11.5 USEPA Regulations 40 CFR Part 136, Appendix B, "Guidelines Establishing Test procedures for the Analysis of Pollutants", July 1992.

11.6 USEPA Test Methods for Evaluating Solid Waste (SW-846); Method 8000: Gas Chromatographic Methods; September 1986.

11.7 USEPA Test Methods for Evaluating Solid Waste (SW-846); Method 8015: Method for General Volatiles Analysis; September 1986

11.8 USEPA Test Methods for Evaluating Solid Waste (SW-846); Method 8020; Aromatic Compounds by Gas Chromatography; September 1986

11.9 USEPA, "Guidance on Evaluation, Resolution, and Documentation of Analytical Problems Associated with Compliance Monitoring", EPA 821-B-93-001; U.S. Government Printing Office, Washington D.C., June, 1993.

Figure 1: GCMS trace of typical gasoline.

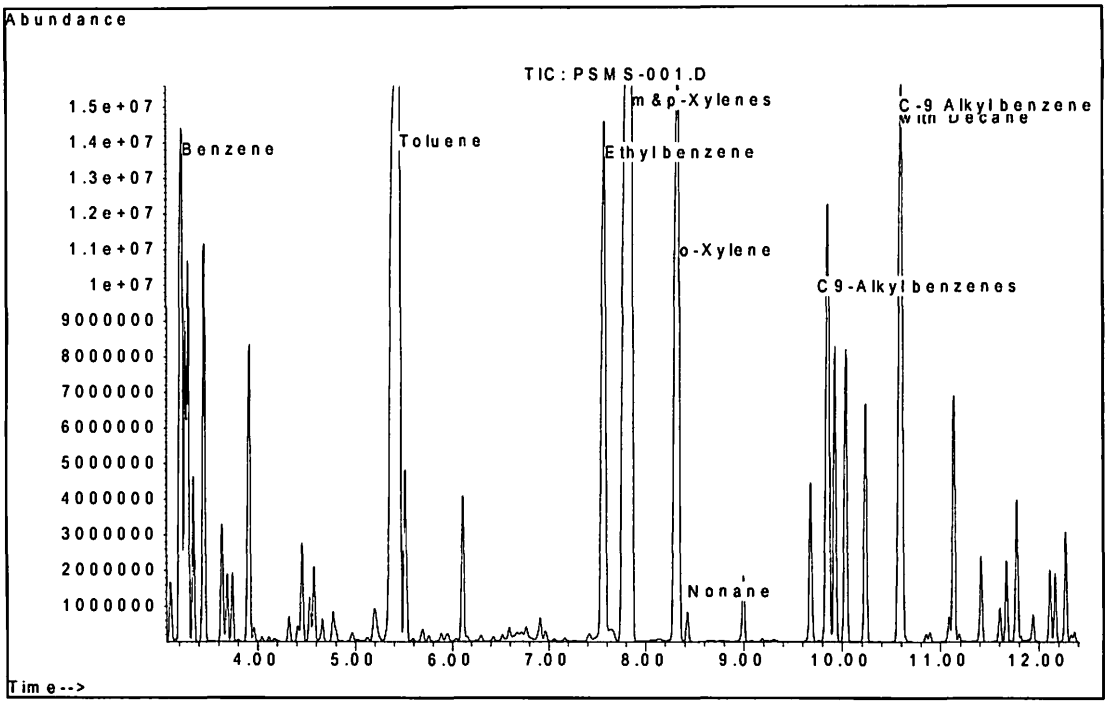


Figure 1: A fresh gasoline analyzed by GCMS to determine compounds present in the C_6 to C_{10} range. BTEX compounds are commonly analyzed by volatiles methodology. Nonane elutes soon after o-Xylene. A single peak at 9min appears to be an olefin and the next 6 peaks are C_9 alkyl benzenes with the last one co-eluting with Decane.

Method AK 102AA

For Determination of Aromatic and Aliphatic Hydrocarbons in Diesel Range Organics
Version 6-30-98

1. Scope & Application

1.1 This method is used for the extraction, fractionation, and quantification of aromatic and aliphatic compounds in the diesel range. Adopted methodology by the Alaska Department of Environmental Conservation (ADEC) has established guidelines defining gasoline range organics (GRO), diesel range organics (DRO), and residual range organics (RRO) for gross organic measurements by Gas Chromatography. The intention of this method is to use these existing criteria and provide guidance for the fractionation of aromatic and aliphatic compounds within these ranges.

1.2 This, and most other aliphatic aromatic, fractionation methods are based on the EPA SW-846 Method 3630 and related techniques employed throughout the petroleum industry.

1.3 This method provides guidance for laboratories interested in performing aromatic and aliphatic fractionation. It also defines general quality control guidelines, reporting limits, and control limits to be used until statistical data is available.

1.4 This method is designed for the fractionation of aromatic / aliphatic compounds in the diesel range. This has been defined as the beginning of C_{10} to the beginning of C_{25}. This range includes: kerosene, several types of jet fuel, several types of motor fuels commonly referred to as diesel fuels, and several light heating oils.

1.5 It is important to note fuels are crude oil distillates. This method is designed to accurately measure aromatic and aliphatic compounds that fall only between the listed n-alkane hydrocarbons. Because distillates are complex mixtures of hydrocarbons, they may extend beyond the ranges defined by the ADEC.

1.6 This is a performance-based method. EPA has recently published guidelines for performance-based methodology -- 62 FR 52098. The intention is to encourage method development within the laboratory community that will 1) decrease costs of analysis, 2) increase analytical precision and accuracy, 3) allow laboratories to better fit methods to data quality objectives.

1.7 Being a performance-based method, heavy reliance on performance evaluation samples will be required. Laboratories shall request, analyze, and submit performance evaluation samples on a periodic basis to retain ADEC approval.

1.8 This document is meant to be a guidance document; it shall not take the place of an individual laboratory Standard Operating Procedure or training program. Each laboratory shall maintain a Standard Operating Procedure that thoroughly describes the method, techniques employed, and verification of method performance. The laboratory shall, also, maintain training records for analysts who perform tasks related to this method. Major variances from this method shall be disclosed on data report forms.

2 Summary of Method

2.1 While several techniques are available for aromatic and aliphatic fractionation analysis that may produce the desired results, the method listed has been found preferable.

2.2 The extraction, fractionation, and quantification of diesel range aromatic and diesel range aliphatic hydrocarbons are described.

2.3 Hydrocarbons extracted from a water, soil, or sludge sample are extracted with methylene chloride and concentrated in accordance with AK102.

2.4 Methylene chloride in the extracts is exchanged for n-hexane or another appropriate non-polar solvent and passed through a bed of silica gel. The silica gel is first washed with the non-polar solvent to collect the aliphatic hydrocarbons, then with a moderately polar solvent to collect aromatic hydrocarbons. The washes are concentrated for analysis.

2.5 Concentrated aromatic and aliphatic samples are analyzed by gas chromatography (GC). The GC shall be equipped with an oven capable of temperature programming and an analytical column capable of separating diesel range compounds within the specifications outlined in this document. It shall also be equipped with a detector capable of detecting carbon or carbon ions -- the typical detector is the Flame Ionization Detector (FID), an Atomic Emission Detector (AED), or other detector capable of measuring the amount of carbon present in a sample independent of compound may be used. Data shall be collected by a data collection system capable of providing a chromatographic trace and integration of the selected hydrocarbon range.

3 Definitions

3.1 Gasoline Range Organics - Organic compounds which elute by gas chromatography between the beginning of n-C_6 and the beginning of n-C_{10}.

3.2 Diesel Range Organics - Organic compounds which elute by gas chromatography between the beginning of n-C_{10} and the beginning of n-C_{25}.

3.3 Residual Range Organics - Organic compounds which elute by gas chromatography between the beginning of n-C_{25} and the end of n-C_{36}.

3.4 Instrument Blank - A clean solvent analyzed to demonstrate the cleanliness of the analytical system.

3.5 Analytical Batch - A set of samples, not to exceed 20, which are extracted, concentrated, and fractionated together. Each analytical batch shall consist of 20 or fewer samples, a method blank, two laboratory control samples, and a matrix spike.

3.6 Method Blank - A sample of clean sand or clean water that is spiked with surrogate compounds, extracted, and fractionated along with the analytical batch of samples.

3.7 Retention Time Marker - A standard used to demonstrate the integration ranges for GRO, DRO, and RRO.

3.8 Initial Calibration - A set of standards used to define the concentration calibration

range of the gas chromatograph. The concentration of the lowest standard must be between 3 and 5 times the method detection limit for this analysis. The initial calibration mixture is a mixture of several compounds within the proper range. These compounds shall span the entire GRO, DRO, or RRO ranges.

3.9 Calibration Verification - A standard, independent of the initial calibration mixture, used to verify the accuracy of the initial calibration. For this method it is common to use a diesel fuel #2 since over 95% of these compounds elute within the DRO range.

3.10 Continuing Calibration - A mid-range calibration standard used to verify the initial calibration while analyzing samples. A continuing calibration standard shall be analyzed with every 10 analytical injections on the gas chromatograph.

3.11 Surrogate Standard Compounds - Compounds not typically present in GRO, DRO, or RRO hydrocarbons, which are placed in known quantities in each sample, method blank, laboratory control sample, and matrix spike to determine the recovery and accuracy of the analysis. The surrogate mixture shall contain, at a minimum, one aromatic compound and one aliphatic compound. A secondary use of the surrogate standard is to demonstrate the effectiveness of the fractionation. Control limits shall be placed on the amount of surrogate breakthrough observed in each sample, method blank, laboratory control sample, and matrix spike.

3.12 Matrix Spiking / Laboratory Control Compounds - A combination of aromatic and aliphatic compounds added to laboratory control samples and matrix spikes to demonstrate laboratory precision and accuracy.

3.13 Silica Gel Breakthrough – Defined as the effect of using either inactive silica gel, too much solvent, inappropriate solvent, or overloading on silica gel column. Surrogate compounds are typically used to determine whether column breakthrough has occurred.

3.14 Aromatic Compounds - Hydrocarbon compounds which are related to benzene.

3.15 Aliphatic Compounds - Paraffins, olefins, branched paraffins, and cyclic paraffins. These compounds have no or few carbon - carbon double bonds and make up the majority of fuels

3.16 Polar Compounds – Typically, associated with biomass. In the terms of this method, these are considered undesirable compounds and are removed if proper corrective action techniques are used.

3.17 Method Detection Limit (MDL) – The minimum concentration of a compound that can be measured and reported with 99 percent confidence that the value is greater than zero, determined from analysis of a sample in a given matrix containing the analyte. (See 40 C.F.R. 136, Appendix B, for method of determining method detection limit. Each laboratory must demonstrate and periodically maintain method detection limits for each analyte of interest. A method detection limit is a statistical quantity defined as the point where one has a 99% confidence they are not seeing either a false positive or a false negative. Near the MDL the confidence in quantification is very low.)

3.18 Quantification Limit - Practical quantitation limit (PQL) is a certain point where

one has a 95% confidence in the quantification of a substance. Practical quantitation limits (PQL) for this method for analysis of DRO must not exceed 20 mg/kg for soils and 2 µg/L for waters.

3.19 Laboratory Control Sample and Laboratory Control Sample Duplicate (LCS/LCSD) - These samples are used by the laboratory to demonstrate a method's precision and accuracy. These are samples identical to a method blank with the exception they are spiked with a known amount of analyte. They are taken through the entire extraction and analytical process.

3.20.1 Matrix Spike - An actual sample that is spiked with a known amount of analyte. This sample can give valuable information about the behavior of analytes in this sample and may be extrapolated to other samples from the same area.

4 Interferences

4.1 Solvents, reagents, glassware, and other sample processing hardware may yield discrete artifacts and/or elevated baselines causing misinterpretation of gas chromatograms. All of these materials must be demonstrated to be free from interference under the conditions of the analysis, by analyzing reagent and method blanks.

4.2 High purity reagents must be used to minimize interference problems.

4.3 Washing all glassware with hot soapy water and then rinsing with warm tap water, acetone, and methylene chloride reduces method interferences.

4.4 Contamination by carryover can occur whenever high-level and low-level samples are sequentially analyzed. Whenever an unusually concentrated sample is analyzed, it must be followed by the analysis of a system solvent blank to check for cross-contamination.

4.5 Matrix interferences may be caused by contaminants that are co-extracted from the sample. The extent of matrix interference will vary considerably from one source to another depending upon the nature and diversity of the site being sampled. Many polar compounds commonly attributed to "biogenic" sources should be removed by the silica gel if properly used. Several petroleum precursors are present in aging vegetation and peat; these compounds will not be removed using this technique.

4.6 The leaching of plasticizers and other compounds have been observed from commercially available silica gel cartridges used to fractionate DRO and RRO sample extracts. Concerns of this nature must be continuously monitored and documented by analysis of Laboratory Method Blanks.

4.7 Many compounds elute along with the C_8 and C_9 alkyl benzenes. Chromatography should be adequate to determine these compounds from aliphatic compounds. Interpretation should be supervised and reviewed by experienced chemists.

5 Health and Safety

The toxicity and carcinogenic nature of each reagent used in this method has not been

precisely defined. Each chemical compound should be treated as a potential health hazard. Exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current safety program to minimize exposure and potential hazards from personnel. A reference file of material safety data sheets (MSDS) shall be made available to all personnel.

6 Apparatus and Materials

6.1 Equipment

6.1.1 Gas Chromatograph: An analytical system with temperature programmable gas chromatograph for use with capillary columns is required. The data system must be capable of storing and reintegrating chromatographic data and must be capable of determining peak areas using a forced baseline projection.

6.1.2 Recommended chromatographic column: A J&W DB-5MS 30m x 0.32mm ID x 0.10µm stationary phase has been successfully used. Any column capable of separating diesel and residual range compounds with minimal column bleed may be used.

6.1.3 A concentration apparatus capable of using clean air or nitrogen to remove excess solvent from samples shall be used. These systems range from a combination of Kuderna-Danish concentrators and N-Evap apparatus, to automated Turbo-Vap systems.

6.1.4 Soil extraction equipment: Soxhlet continuous extractors and ultrasonic cell disrupters have been used for the extraction of soil samples.

6.1.5 Analytical balances:

6.1.5.1 An analytical balance capable of measuring 0.0001g is required for standards preparation.

6.1.5.2 An analytical balance capable of measuring 0.01g is required for measuring sample weights.

6.1.6 Drying oven: an oven capable of maintaining 150°C is used for drying of sodium sulfate and activation of silica gel.

6.2 Glassware

6.2.1 Beakers - 250mL or 400mL.

6.2.2 2L separatory funnels or equivalent (continuous extractors, etc.).

6.2.2 Long stemmed funnels.

6.2.3 Kuderna-Danish concentrator or equivalent (Turbo Vap tubes, etc.).

6.2.4 10mL graduated disposable pipettes or equivalent.

6.2.5 Graduated cylinders - 50mL & 100mL.

6.2.6 Graduated centrifuge tubes or equivalent - 10mL or 15mL.

6.2.7 Autosampler vials or extract containers.

6.1.8 Syringes - 10, 25, 100, 500, and 1000µL.

6.3 Reagents

6.3.1 Methylene chloride - analytical grade or better, must be demonstrated to be below method detection limits for diesel and residual range contaminants.

6.3.2 n-Hexane - analytical grade or better, must be demonstrated to be below method detection limits for diesel and residual range contaminants.

6.3.3 Ottawa sand - cleaned beach sand used for soil method blanks.

6.3.4 Sodium sulfate - Anhydrous, granulated, used for drying soil samples and all methylene chloride extracts.

6.3.5 Silica gel - Anhydrous, 60 - 100 mesh has been used successfully. Prepacked extraction cartridges may be used provided they meet the quality control performance criteria listed in this document.

IMPORTANT: silica gel should be activated by placing in a 150°C oven prior to use, prolonged exposure to moist air will cause high surrogate breakthrough in samples, method blanks, laboratory control samples, and matrix spikes.

6.3.6 Glass wool - Pesticide grade or better.

6.4 Standards

6.4.1 Retention time marker - shall consist of a minimum of n-C_{10}, n-C_{25}, and n-C_{36} (if the optional RRO analysis is used concurrently with DRO). More n-alkanes are recommended. This mixture is typically injected into the GC at a concentration of 50µg/mL for each compound.

6.4.2 Initial calibration mixtures: Since it is impractical and nearly impossible to use a commercial diesel range distillate for calibration a synthetic mixture must be used. The use of a Flame Ionization Detector or other "carbon counting" detector allows a free association between fuel-derived hydrocarbon compounds providing little or no injector discrimination is present.

Choose a minimum of three -- recommend five or more -- which span the entire diesel range. The concentration of the standard is the total of all the individual compounds.

Each compound should be in the same concentration as the others in solution. A minimum of five dilutions of this mixture must be used for calibration purposes. The lowest concentration standard shall be within a factor of three to five of the method detection limit or at the reporting limit, whichever is lower. The highest concentration shall define the upper limit to the calibration. Sample extracts that

contain concentrations higher than the calibration curve shall be diluted and reanalyzed.

6.4.2.1 Aromatic - A minimum of three aromatic compounds, which span the diesel range, should be used for calibration purposes. Polynuclear aromatic hydrocarbons (PAHs) generally suit the purpose of this calibration.

6.4.2.2 Aliphatic - A minimum of three aliphatic compounds, which span the diesel range, should be used for calibration purposes. N-alkanes: C_{11}, C_{15}, C_{17}, C_{18}, and C_{24} have been successfully used.

6.4.3 Calibration verification mixture - A #2 diesel fuel diluted to 1000µg/mL has been successfully used. Any hydrocarbon mixture where more than 95% of the hydrocarbon elutes in the diesel range and is independent of the initial calibration may be used.

6.4.4 Continuing Calibration mixture - A mid-level standard using the same or similar compounds used in the initial calibration mixture should be prepared for this purpose.

6.4.5 Surrogate standard mixture - A surrogate mixture shall be made in methylene chloride and shall contain compounds from the three major fractions present in most samples -- aliphatic, aromatic, and polar. Working standards should be prepared to yield a concentration of 100µg/mL of the proper surrogate in each of the final fractions.

6.4.5.1 Squalane has been successfully used for the aliphatic surrogate; although it elutes in the residual range no problems have been observed.

6.4.5.2 o-Terphenyl has been used as an aromatic surrogate with great success; few interference problems have been observed.

6.4.5.3 Tetrahydronaphthol has been successfully used as a polar surrogate to monitor the elution of polar compounds with the aromatic fraction.

Note: The surrogate standard mixture shall be made up in methylene chloride or hexane, NOT methanol or acetone, even small amounts of these solvents greatly affect the polarity of the final solutions and will be detrimental to the fractionation.

6.4.6 Internal standard mixture (optional) - 5-α-Androstane may be used as an optional internal standard if deemed necessary by the analyst.

6.4.7 Laboratory control sample / matrix spike mixture - A mixture of aromatic and aliphatic compounds -- a minimum of three each -- shall be used as a laboratory control sample / matrix spike mixture. The mixture shall contain both aromatic and aliphatic compounds and have a concentration sufficient such that a final concentration in each extract fraction is 50µg/mL of each component. For example, if five aromatics and five aliphatics are used then the final concentration

of each fraction should be 250µg/mL.

Note: The laboratory control sample / matrix spike mixture must be made up in methylene chloride or hexane, NOT methanol or acetone, even small amounts of these solvents greatly affect the polarity of the final solutions and will be detrimental to the fractionation.

7 Sample Collection, Preservation, and Handling

7.1 Aqueous samples are collected in 1-liter amber glass bottles with Teflon-lined screw caps.

7.2 Soil and sediment samples are collected in 4 oz. (120 mL) amber wide-mouth glass jars with Teflon-lined screw caps.

7.3 Aqueous samples must be preserved at the time of sampling by the addition of a suitable acid to reduce the pH of the sample to less than 2.0. This may be accomplished by the addition of 5 mL of 1:1 HCl to a 1 liter sample. The use of alternative acids is permissible. Following collection and addition of acid, the sample must be cooled to 4°C.

7.4 Soil and sediment samples must be cooled to 4°C immediately after collection.

7.5 A chain of custody form must accompany all aqueous, soil and sediment samples, documenting the time and date of sampling and any preservative additions.

7.6 Aqueous samples must be extracted within 7 days of collection, and analyzed within 40 days of extraction.

7.7 Soil and sediment samples must be extracted within 14 days of collection, and analyzed within 40 days of extraction.

8 Procedure

8.1 Sample Preparation - Samples are extracted using methylene chloride, and, later, solvent-exchanged into hexane. An acceptable extraction procedure for water samples is a separatory funnel liquid/liquid extraction technique based upon SW-846 Method 3510A; continuous liquid/liquid extraction has also proven effective. For soil or sediment samples, use of a Soxhlet or Soxtec technique is recommended. Alternative extraction procedures are acceptable, provided that the laboratory can document acceptable performance.

8.1.1 Water Extraction

8.1.1.1 Mark the meniscus on the 1-liter sample bottle (for later volume determination) and transfer it to a 2-liter separatory funnel. For blanks and quality control samples, pour 1 liter of reagent water into the separatory funnel. Check the pH of the sample with wide-range pH paper. Note the pH in a laboratory logbook or preparatory sheet.

The pH of the sample need not be adjusted.

8.1.1.2 Add 1.0 mL of the surrogate spiking solution to all samples, blanks, laboratory control samples, and matrix spikes. For samples selected for spiking, add laboratory control sample / matrix spike solution.

8.1.1.3 Add 60mL methylene chloride to the sample bottle to rinse the inner walls of the container and add this solvent to the separatory funnel.

8.1.1.4 Seal and shake each separatory funnel vigorously for 2 minutes with periodic venting to release excess pressure.

NOTE: Methylene chloride creates excessive pressure very rapidly; therefore, venting into a hood should be done immediately after the separatory funnel has been sealed and shaken once.

8.1.1.5 Allow the organic layer to separate from the water phase for a minimum of 10 minutes. If the emulsion interface between layers is more than one-third the size of the solvent layer, the analyst must employ mechanical techniques to complete the phase fractionation. The optimum technique depends upon the sample and may include stirring, filtration of the emulsion through glass wool, centrifugation, or other physical methods.

8.1.1.6 Prepare a filtration apparatus by suspending a funnel with either filter paper or a plug of glass wool and bed of sodium sulfate over a receiving vessel (a Kuderna-Danish vessel or Turbo-Vap tube).

8.1.1.7 Pour organic extract through the sodium sulfate bed and allow to drain into the receiving vessel. Be sure to rinse sodium sulfate thoroughly with methylene chloride after it had drained.

8.1.1.8 Repeat the extraction two more times using additional 60 mL portions of solvent. Combine the three solvent extracts in a 250-mL Erlenmeyer flask. (Steps 8.1.1.3 to 81.1.5)

8.1.1.9 For sample volume determination add water to the sample bottle to the level of the meniscus previously marked then transfer this water to a graduated cylinder.

8.1.2 Soil Extraction using ultrasonic probe

8.1.2.1 Weigh approximately 25g of soil into a 250mL beaker.

8.1.2.2 Add surrogate standard solution to all samples, blanks, laboratory control samples, and matrix spikes. Add laboratory control sample / matrix spike mixture to appropriate samples.

8.1.2.2 Mix anhydrous sodium sulfate into soil using a metal spatula. This should be done until the soil / sodium sulfate mixture has the consistency of beach sand.

8.1.2.3 Add approximately 60mL of methylene chloride until solids have

been covered to a depth of about ½ inch.

8.1.2.4 Place mixture under ultrasound horn and start sonication for two minutes.

8.1.2.5 Prepare a filtration apparatus by suspending a funnel with either filter paper or a plug of glass wool and bed of sodium sulfate over a receiving vessel (a Kuderna-Danish vessel or Turbo-Vap tube).

8.1.2.6 When sonication has finished, pour the solvent through the sodium sulfate bed and allow to drain into the receiving vessel. Be sure to rinse sodium sulfate thoroughly with methylene chloride after it has drained.

8.1.2.7 Repeat steps 8.1.2.3 - 8.1.2.6 two more times.

8.1.2.8 Go to sample concentration and solvent exchange step.

8.1.2.9

8.1.3 Extract concentration and solvent exchange

8.1.3.1 Using concentration apparatus, concentrate sample until its volume is less than 3mL.

8.1.3.2 Add nonpolar solvent (n-hexane); be sure to thoroughly mix the solution since methylene chloride may tend to stay at the bottom of the container.

8.1.3.3 Concentrate extract down to 5mL.

8.2 Aromatic / Aliphatic Fractionation

8.2.1 Cut the top off a 10mL disposable volumetric Pasteur pipette using a triangular file.

8.2.2 Place a small plug of glass wool into the pipette and slide it down into the taper.

8.2.3 Add a few grams of Ottawa sand to cover the glass wool and provide a flat bed for the silica gel.

8.2.4 Add silica gel to the pipette, with occasional shaking to ensure uniform packing, up to the 3mL mark.

8.2.5 Add another few grams of Ottawa sand to provide some protection to the silica gel bed.

8.2.6 Note the mark where the top of the silica gel is. Add n-hexane to the pipette up to one of the marks on the pipette where the analyst can track the volume of hexane.

8.2.7 When hexane begins to drip out the bottom of the pipette note the volume of hexane added to the top and the volume left. This will be the column volume. Allow one more column volume to pass through to rinse the silica gel and discard

the hexane.

8.2.8 When the hexane level has reached the top of the sand, add 1.0mL of hexane extract. Allow this to flow down into the sand before adding more hexane. Begin collecting hexane in graduated 15mL-centrifuge tube or volumetric Kuderna-Danish tube when ½ to ¾ of a column volume of hexane has passed through the column.

8.2.9 Each solvent wash should consist of 1.5 to 2.5 column volumes to eliminate break through. With experience, the analyst should be able to determine the amount of wash needed.

8.2.10 When the hexane level has dropped into the sand, slowly add pure methylene chloride to the top of the column.

8.2.11 When ½ to ¾ of a column wash of methylene chloride has passed through the silica gel, change collection tubes and mark the hexane fraction as Aliphatic.

8.2.12 Continue adding methylene chloride until 1.5 to 2.5 volumes have passed.

8.2.13 If the polar compounds are of interest, add a third wash of 5 - 10% methanol in methylene chloride. Otherwise, finish the methylene chloride wash with one additional column volume. Remove this fraction and label it Aromatic.

Note: The amount of solvent in each receiver should be approximately the same as the calculated column volume times the multiplication factor in use for the lab (1.5 to 2.5).

Note: Column overloading is a common occurrence. Dilution of samples prior to fractionation may be necessary to avoid unwanted breakthrough.

8.2.14 Using an appropriate concentration device, concentrate each fraction down to 1.0mL. If internal standard is used, add it now. Samples are ready for analysis.

8.3 Analysis

8.3.1 Gas Chromatograph Conditions (Recommended)

Parameter	Setting
Gas	Helium
Linear velocity	60 - 65cm/s
Initial Temp.	35°C
Initial Time	4min.
Rate	15°C/min.
Final Temp.	250°C
Hold	0min.
Rate II	25°C/min.
Final Temp. II	350°C
Hold II	5 - 10min.
Injector Temp.	310°C; Note: higher temperatures cause thermal cracking of hydrocarbons.
Detector Temp.	355°C

8.3.2 Gas Chromatograph Sequencing - A typical GC sequence must include a 24 hour retention time marker, a continuing calibration standard for every 10 injections -- that is, a beginning continuing calibration standard, and one after each subsequent 10 injections -- and an ending continuing calibration standard. Each sample batch should be analyzed in one sequence on the same instrument.

8.3.3 Calibration - A minimum of 5 concentrations of standard must be used to define the calibration curve. The concentration of each standard is the total of the concentrations of analytes present in that standard, hence, 5 analytes at 50µg/mL has a total concentration of 250µg/mL.

8.3.3.1 The lowest standard shall be equivalent to the reporting limit or a value three to five times the method detection limit, whichever is lower.

8.3.3.2 The highest concentration standard shall define the highest extract concentration that may be reported without dilution.

8.3.3.3 Whenever possible use a least squares linear regression for calibration. Quadratic curves and average of response factors are acceptable provided adequate quality control and performance parameters are consistently met.

9. Calculations

9.1 Response Factors

$$Response\,Factor = \frac{(Area_{x,std})}{(C_{x,std})} \qquad \text{Eq. 1}$$

Where

$A_{x,std}$ = Area of analyte in standard.
$C_{x,std}$ = Concentration of analyte in Standard in µg/mL.

9.2 Concentrations

9.2.1 Soil External Standard (example) – many software packages report concentrations of extracts without any problem. The following is for those cases where this is not done. It requires an average of response factors.

$$Concentration\,in\,Soil(mg/Kg) = \frac{(Area_x)(df)(V_f)(1000\mu g/mg)}{(rf)(m_f)(W_i)} \qquad \text{Eq. 2}$$

Where

A_x = Area of analyte in extract.
df = Dilution Factor of extract.
V_f = Final volume of extract after concentration step.
rf = Response factor.
m_f = Fractional dry mass (% Dryness)
W_i = Initial Weight of soil sample.

Note: If instrument reports concentration in extract; that value can replace the ($Area_x$/rf) portion of the equation.

9.2.2 Water External Standard (example) – many software packages report concentrations of extracts without any problem. The following is for those cases where this is not done. It requires an average of response factors.

$$Concentration\,in\,Water(\mu g/L) = \frac{(Area_x)(df)(V_f)}{(rf)(V_i)} \qquad \text{Eq. 3}$$

Where

A_x = Area of analyte in extract.
df = Dilution Factor of extract.
V_f = Final volume of extract after concentration step.
rf = Response factor.
V_i = Initial volume of water (aqueous) sample.

Note: If instrument reports concentration in extract; that value can replace the ($Area_x$/rf) portion of the equation.

9.3 Fractional Mass of a soil – This is the fractional version of %Dryness for use in soil calculations.

$$Fractional\ Mass = \frac{(m_d)}{(m_s)} \qquad \text{Eq. 4}$$

Where

m_d = Weight of dried soil.
m_s = Weight of sample before drying.

9.4 Relative Percent Difference

$$RPD = \frac{(X_1 - X_2)}{(X_1 + X_2)/2} * 100\% \qquad \text{Eq. 5}$$

10 Quality Control

10.1 Retention Time Markers

10.1.1 A retention time marker must be analyzed at least once every 24-hour period or once each day of instrument operation.

10.1.2 The analyst must use the retention times for the ranges of interest from three separate retention time markers to determine acceptable retention time variation.

10.1.3 If the retention time of a retention time marker standard falls outside the established window, the retention time must be updated and a new retention time window established.

10.2 Initial Calibration – A minimum five-point calibration must be performed to establish the working range of the Gas Chromatograph.

10.2.1 An initial calibration must be made up for each fraction – aromatic and aliphatic – and must contain a minimum of three compounds.

10.2.2 The initial calibration should contain hydrocarbons representative of the particular fraction to be analyzed.

10.2.3 The lowest concentration must be between 3 and 5 times the method detection limit concentration or at the reporting limit concentration, whichever is lower.

10.2.4 The highest concentration will define the upper limit concentration that may be reported without extract dilution.

10.2.5 If a linear regression is used (recommended) the coefficient of correlation must be 0.98 or higher.

10.2.6 If an average of response factors is used the maximum %RSD must be no greater than 15%.

10.2.7 A quadratic calibration may be used if the GC software allows this type of calibration. The coefficient of correlation must not fall below 0.98.

10.2.8 All data points in the calibration should be weighted equally.

10.2.9 Corrective Actions

a) If the initial calibration is outside the control limits, analysis shall not be performed.
b) Reintegrate all standards.
c) Prepare and reanalyze a new curve.

10.3 Second Source Calibration Verification – A standard used to verify the initial calibration.

10.3.1 The second source calibration verification may be made up from a standard similar to the initial calibration at an intermediate level.

10.3.2 The second source compounds must be obtained from a separate source than the initial calibration compounds.

10.3.3 A middle diesel range distillate may be used in the place of a synthetic calibration standard provided more than 95% of the hydrocarbon area elutes within the ADEC defined diesel range.

10.3.4 The second source calibration verification standard may also be used as the continuing calibration standard.

10.3.5 The recovery of the second source calibration verification must be +/- 15% of the true value.

10.3.6 Corrective Actions

a) If the second source verification standard is outside the control limits, analysis shall not be performed.
b) Reanalyze the second source calibration verification standard.

c) Reprepare a new standard.
d) Reprepare and analyze a new initial calibration.

10.4 Instrument Blank

10.4.1 Must be below reporting limits before proceeding with further analysis.

10.4.2 Must be analyzed at least once every 24 hours of instrument operation.

10.4.3 An instrument blank is recommended after samples high in concentration.

10.4.4 Corrective Actions

a) If an instrument blank is outside the limits all samples associated with that blank must be reanalyzed.

10.5 Continuing Calibration Standard

10.5.1 The Continuing Calibration Standard may be made up from a standard similar to the initial calibration at an intermediate level.

10.5.2 A middle diesel range distillate (e.g. DF-2) may be used in the place of a synthetic calibration standard provided more than 95% of the hydrocarbon area elutes within the ADEC defined diesel range.

10.5.3 The continuing calibration standard may also be used as the second source calibration verification.

10.5.4 The recovery of the second source calibration verification must be +/- 15% of the true value.

10.5.5 A continuing calibration standard must be analyzed at the beginning of an analytical run, once every 10 injections on the GC, and at the close of the run.

10.5.6 Corrective Actions

a) If a Continuing Calibration Verification is outside the limits, all samples associated with that standard must be reanalyzed.
b) Be certain Continuing Calibration Verification is fresh and within limits.

10.6 Method Blank

10.6.1 The method blank must be made up from a matrix similar to the samples within the analytical batch (e.g. water for aqueous, sand for sandy soil, clean loam for mossy high biomass samples)

10.6.2 Surrogate standards must be added to all method blanks and must fall within the window of 70 – 120% of the true values.

10.6.3 The method blank must be free of contamination (below reporting limits) within the specified range.

10.6.4 Corrective actions

a) Reanalyze method blank being sure no instrument carryover is present.
b) If problem persists, or surrogates are outside acceptable ranges, associated analytical batch must be re-extracted and analyzed.

10.7 Laboratory Control Sample and Laboratory Control Sample Duplicate (LCS/LCSD).

10.7.1 The LCS/LCSD/Matrix Spiking working standard must be made up of a synthetic mixture of analytes. A minimum of three aromatic and three aliphatic compounds must be used for each range (DRO, RRO, GRO).

10.7.2 The LCS/LCSD should be made up from a matrix similar to the samples within the analytical batch (e.g. water for aqueous, sand for sandy soil, clean loam for mossy high biomass samples)

10.7.3 Surrogate standards must be added to all LCS/LCSD and must fall within the window of 70 – 120% of the true values.

10.7.4 Matrix spiking/LCS compounds must be added to all LCS/LCSD samples and must fall within the window of 70 – 120% of the true values.

10.7.5 Compounds from the other fraction must not exceed 10% (e.g. the aliphatic LCS/LCSD samples may not have more than 10% recovery of any single aromatic LCS/LCSD/Matrix Spiking compound or visa versa).

10.7.6 The duplicate must have a relative percent difference of less than 20%.

10.7.7 Corrective actions

a) Reanalyze LCS/LCSD being sure no instrument carryover is present.
b) If problem persists, or surrogates are outside acceptable ranges, associated analytical batch must be re-extracted, re-fractionated, and/or re-analyzed.

10.8 Matrix Spike (MS)

10.8.1 The LCS/LCSD/Matrix Spiking working standard must be made up of a synthetic mixture of analytes. A minimum of three aromatic and three aliphatic compounds must be used for each range (DRO, RRO, GRO).

10.8.2 The matrix spike must be made up from a sample within the analytical batch.

10.8.3 Surrogate standards must be added to all matrix spike samples and should fall within the window of 50 - 150% of the true values.

10.8.4 Matrix spiking/LCS compounds must be added to all matrix spike samples and should fall within the window of 50 - 150% of the true values.

10.8.5 Compounds from the other fraction must not exceed 10% recovery (e.g. the

aliphatic matrix spike samples may not have more than 10% recovery of any single aromatic LCS/LCSD/Matrix Spiking compound or visa versa).

10.8.6 Corrective actions

No corrective actions are required for a matrix spike that is out of compliance.

10.9 Surrogate Spikes

10.9.1 At least one aromatic and one aliphatic surrogate compound which does not coelute or otherwise interfere with the analytes of interest must be added to each sample, method blank, LCS/LCSD, and matrix spike.

10.9.2 Since diesel and residual range compounds are often analyzed together, one compound per fraction will suffice for the modified AK102/103 combined method.

10.9.3 The recovery of surrogate standards must not be outside the range 70 – 120% for method blanks and LCS/LCSD samples.

10.9.4 The recovery of surrogate standards should not be outside the range 50 - 150% for all remaining samples and matrix spikes.

10.9.5 Surrogate compounds from the other fraction must not exceed 10% recovery in a given fraction (e.g. the aliphatic samples or matrix spikes may not have more than 10% recovery of any single aromatic surrogate compound or visa versa).

10.9.6 The polar surrogate shall not be observed above 10% recovery in any sample, method blank, LCS/LCSD, or matrix spike.

10.9.7 Corrective Actions

a) If the surrogates for a sample are out of limits, that sample must be re-extracted, re-fractionated, and/or re-analyzed.
b) If a surrogate is out of limits in the same direction (e.g. low both times) for a second time, the report shall reflect a matrix effect.
c) If a surrogate is higher than limits for the opposing fraction, that sample shall be re-extracted, re-fractionated, and/or re-analyzed. Care must be taken to ensure the quality and the activity of the silica gel or alumina or other adsorptive material in the fractionation column.
d) If a surrogate compound is out of limits for a method blank or LCS/LCSD sample, that sample must first be re-analyzed; then, if still out, the entire analytical batch must be re-extracted, re-fractionated, and re-analyzed.

11. References

11.01 Alaska Department of Environmental Conservation, Methods AK102 & AK103.

11.02 The Federal Register, 62 FR 52098, Oct 1997.

11.03 Massachusetts Department of Environmental Protection and ABB Environmental Services, Inc., Wakefield, MA "Interim Petroleum Policy: Development of Health-based Alternative to the Total Petroleum Hydrocarbon (TPH) Parameter", August 1994.

11.04 USEPA, "Measurement of Petroleum Hydrocarbons: Report on Activities to Develop a Manual" Prepared by Midwest Research Institute, Falls Church, VA, under EPA Contract #68-WO-0015, WA No. 4; submitted to USEPA Office of Underground Storage Tanks, Washington, DC; November 20, 1990.

11.05 USEPA Regulations 40 C.F.R. 136, Appendix B, "Guidelines Establishing Test procedures for the Analysis of Pollutants", July 1992.

11.06 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 3510: Separatory Funnel Liquid-Liquid Extraction; September 1986.

11.07 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 3540: Soxhlet Extraction; September 1986

11.08 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 3630: Silica Gel Cleanup; September 1986

11.09 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 8000: Gas Chromatography; September 1986

11.10 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 8100: Polynuclear Aromatic Hydrocarbons; September 1986

11.11 Wisconsin Department of Natural Resources, "Modified DRO - Method for Determining Diesel Range Organics", PUBL-SW-141, 1992

11.12 USEPA, "Guidance on Evaluation, Resolution, and Documentation of Analytical Problems Associated with Compliance Monitoring", EPA 821-B-93-001; U.S. Government Printing Office, Washington D.C., June, 1993

Method AK 103AA
For Determination of Aromatic and Aliphatic Hydrocarbons in Residual Range Organics
Version 6-30-98

1 Scope & Application

1.1 This method is used for the extraction, fractionation, and quantification of aromatic and aliphatic compounds in the residual range. Adopted methodology by the Alaska Department of Environmental Conservation (ADEC) has established guidelines defining gasoline range organics (GRO), diesel range organics (DRO), and residual range organics (RRO) for gross organic measurements by Gas Chromatography. The intention of this method is to use these existing criteria and provide guidance for the fractionation and quantification of aromatic and aliphatic compounds within these ranges.

1.2 This, and most other aliphatic aromatic, fractionation methods are based on the EPA SW-846 Method 3630 and related techniques employed throughout the petroleum industry.

1.3 This method provides guidance for laboratories interested in performing aromatic and aliphatic fractionation. It also defines general quality control guidelines and control limits to be used until statistical data is available.

1.4 This method is designed for the fractionation of aromatic / aliphatic compounds in the residual range. This has been defined as the beginning of C_{25} to the end of C_{36}. This range includes heavy heating oils, lubricating oils, and hydraulic fluids. This method is typically employed along with its diesel range organic counterpart in a combination analysis.

1.5 It is important to note fuels are crude oil distillates. This method is designed to accurately measure aromatic and aliphatic compounds that fall only between the listed n-alkane hydrocarbons. Because distillates are complex mixtures of hydrocarbons, they may extend beyond the ranges defined by the ADEC.

1.6 This is a performance-based method. EPA has recently published guidelines for performance-based methodology -- 62 FR 52098. The intention is to encourage method development within the laboratory community that will 1) decrease costs of analysis, 2) increase analytical precision and accuracy, 3) allow laboratories to better fit methods to data quality objectives.

1.7 Being a performance-based method, heavy reliance on performance evaluation samples will be required. Laboratories shall request, analyze, and submit performance evaluation samples on a periodic basis to retain ADEC approval.

1.8 This document is meant to be a guidance document; it shall not take the place of an individual laboratory Standard Operating Procedure or training program. Each laboratory shall maintain a Standard Operating Procedure that thoroughly describes the method, techniques employed, and verification of method performance. The laboratory shall,

also, maintain training records for analysts who perform tasks related to this method. Major variances from this method shall be disclosed on data report forms.

2 Summary of Method

2.1 While several techniques are available for aromatic and aliphatic fractionation analysis that may produce the desired results, the method listed has been found preferable.

2.2 The extraction, fractionation, and quantification of residual range aromatic and residual range aliphatic hydrocarbons are described.

2.3 Hydrocarbons extracted from a water, soil, or sludge sample are extracted with methylene chloride and concentrated in accordance with AK102 and AK103.

2.4 Methylene chloride in the extracts is exchanged for n-hexane or another appropriate non-polar solvent and passed through a bed of silica gel. The silica gel is first washed with the non-polar solvent to collect the aliphatic hydrocarbons, then with a moderately polar solvent to collect aromatic hydrocarbons. The washes are concentrated for analysis.

2.5 Concentrated aromatic and aliphatic samples are analyzed by gas chromatography (GC). The GC shall be equipped with an oven capable of temperature programming and an analytical column capable of separating residual range compounds within the specifications outlined in this document. It shall also be equipped with a detector capable of detecting carbon or carbon ions -- the typical detector is the Flame Ionization Detector (FID), an Atomic Emission Detector (AED), or other detector capable of measuring the amount of carbon present in a sample independent of the final component that may be observed. Data shall be collected by a data collection system capable of providing a chromatographic trace and integration of the selected hydrocarbon range.

3 Definitions

3.1 Gasoline Range Organics - Organic compounds which elute by gas chromatography between the beginning of n-C_6 and the beginning of n-C_{10}.

3.2 Diesel Range Organics - Organic compounds which elute by gas chromatography between the beginning of n-C_{10} and the beginning of n-C_{25}.

3.3 Residual Range Organics - Organic compounds which elute by gas chromatography between the beginning of n-C_{25} and the end of n-C_{36}.

3.4 Instrument Blank - A clean solvent analyzed to demonstrate the cleanliness of the analytical system.

3.5 Analytical Batch - A set of samples, not to exceed 20, which are extracted, concentrated, and fractionated together. Each analytical batch shall consist of 20 or fewer samples, a method blank, two laboratory control samples, and a matrix spike.

3.6 Method Blank - A sample of clean sand or clean water that is spiked with surrogate compounds, extracted, and fractionated along with the analytical batch of samples.

3.7 Retention Time Marker - A standard used to demonstrate the integration ranges for GRO, DRO, and RRO.

3.8 Initial Calibration - A set of standards used to define the concentration calibration range of the gas chromatograph. The concentration of the lowest standard must be between 3 and 5 times the method detection limit for this analysis. The initial calibration mixture is a mixture of several compounds within the proper range. These compounds shall span the entire GRO, DRO, or RRO ranges.

3.9 Calibration Verification - A standard, independent of the initial calibration mixture, used to verify the accuracy of the initial calibration. Since the residual range is somewhat abbreviated and a single oil or other heavy distillate where over 95% of the hydrocarbon elutes within the carbon range limits, a synthetic calibration verification standard is recommended.

3.10 Continuing Calibration - A mid-range calibration standard used to verify the initial calibration while analyzing samples. A continuing calibration standard shall be analyzed with every 10 analytical injections on the gas chromatograph.

3.11 Surrogate Standard Compounds - Compounds not typically present in GRO, DRO, or RRO hydrocarbons, which are placed in known quantities in each sample, method blank, laboratory control sample, and matrix spike to determine the recovery and accuracy of the analysis. The surrogate mixture shall contain, at a minimum, one aromatic compound and one aliphatic compound. A secondary use of the surrogate standard is to demonstrate the effectiveness of the fractionation. Control limits shall be placed on the amount of surrogate breakthrough observed in each sample, method blank, laboratory control sample, and matrix spike.

3.12 Matrix Spiking / Laboratory Control Compounds - A combination of aromatic and aliphatic compounds added to laboratory control samples and matrix spikes to demonstrate laboratory precision and accuracy.

3.13 Silica Gel Breakthrough – Defined as the effect of using either inactive silica gel, too much solvent, inappropriate solvent, or overloading on silica gel column where compounds which should be retained on the silica gel breakthrough into the fraction. Surrogate compounds are typically used to determine whether column breakthrough has occurred.

3.14 Aromatic Compounds - Hydrocarbon compounds which are related to benzene.

3.15 Aliphatic Compounds - Paraffins, olefins, branched paraffins, and cyclic paraffins. These compounds have no or few carbon - carbon double bonds and make up the majority of fuels

3.16 Polar Compounds – Typically, associated with biomass. In the terms of this method, these are considered undesirable compounds and are removed if proper corrective action techniques are used.

3.17 Method Detection Limit (MDL) – The minimum concentration of a compound that can be measured and reported with 99 percent confidence that the value is greater than zero, determined from analysis of a sample in a given matrix containing the analyte. (See 40 C.F.R. 136, Appendix B, for method of determining method detection limit. Each laboratory must demonstrate and periodically maintain method detection limits for each analyte of interest. A method detection limit is a statistical quantity defined as the point where one has a 99% confidence they are not seeing either a false positive or a false negative. Near the MDL the confidence in quantification is very low.)

3.18 Quantification Limit - Practical quantitation limit (PQL) is a certain point where one has a 95% confidence in the quantification of a substance. Practical quantitation limits (PQL) for this method for analysis of RRO must not exceed 20 mg/kg for soils.

3.19 Laboratory Control Sample and Laboratory Control Sample Duplicate (LCS/LCSD) - These samples are used by the laboratory to demonstrate a method's precision and accuracy. These are samples identical to a method blank with the exception they are spiked with a known amount of analyte. They are taken through the entire extraction and analytical process.

3.19 Matrix Spike - An actual sample that is spiked with a known amount of analyte. This sample can give valuable information about the behavior of analytes in this sample and may be extrapolated to other samples from the same area.

4 Interferences

4.1 Solvents, reagents, glassware, and other sample processing hardware may yield discrete artifacts and/or elevated baselines causing misinterpretation of gas chromatograms. All of these materials must be demonstrated to be free from interference under the conditions of the analysis, by analyzing reagent and method blanks.

4.2 High purity reagents must be used to minimize interference problems.

4.3 Washing all glassware with hot soapy water and then rinsing with warm tap water, acetone, and methylene chloride reduces method interferences.

4.4 Contamination by carryover can occur whenever high-level and low-level samples are sequentially analyzed. Whenever an unusually concentrated sample is analyzed, it must be followed by the analysis of a system solvent blank to check for cross-contamination.

4.5 Matrix interferences may be caused by contaminants that are co-extracted from the

sample. The extent of matrix interference will vary considerably from one source to another depending upon the nature and diversity of the site being sampled. Many polar compounds commonly attributed to "biogenic" sources should be removed by the silica gel if properly used. Several petroleum precursors are present in aging vegetation and peat; these compounds will not be removed using this technique.

4.6 The leaching of plasticizers and other compounds have been observed from commercially available silica gel cartridges used to fractionate DRO and RRO sample extracts. Concerns of this nature must be continuously monitored and documented by analysis of Laboratory Method Blanks.

4.7 Chromatographic columns typically "bleed" stationary phase material at high temperatures. This bleed may interfere with the residual range causing elevated method detection and reporting limits. The analyst should take precautions to either eliminate this or correct for it. Typically, the use of a column compensation program by the gas chromatograph will yield satisfactory results.

5 Health and Safety

The toxicity and carcinogenic nature of each reagent used in this method has not been precisely defined. Each chemical compound should be treated as a potential health hazard. Exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current safety program to minimize exposure and potential hazards from personnel. A reference file of material safety data sheets (MSDS) shall be made available to all personnel.

6 Apparatus and Materials

6.1 Equipment

6.1.1 Gas Chromatograph: An analytical system with temperature programmable gas chromatograph for use with capillary columns is required. The data system must be capable of storing and reintegrating chromatographic data and must be capable of determining peak areas using a forced baseline projection.

6.1.2 Recommended chromatographic column: A J&W DB-5MS 30m x 0.32mm ID x 0.10µm stationary phase has been successfully used. Any column capable of separating diesel and residual range compounds with minimal column bleed may be used.

6.1.3 A concentration apparatus capable of using clean air or nitrogen to remove excess solvent from samples shall be used. These systems range from a combination of Kuderna-Danish concentrators and N-Evap apparatus, to automated Turbo-Vap systems.

6.1.4 Soil extraction equipment: Soxhlet continuous extractors and ultrasonic cell disrupters have been used for the extraction of soil samples.

6.1.5 Analytical balances:

6.1.5.1 An analytical balance capable of measuring 0.0001g is required for

standards preparation.

6.1.5.2 An analytical balance capable of measuring 0.01g is required for measuring sample weights.

6.1.6 Drying oven: an oven capable of maintaining 150°C is used for drying of sodium sulfate and activation of silica gel.

6.2 Glassware

6.2.1 Beakers - 250mL or 400mL.

6.2.2 2L separatory funnels or equivalent (continuous extractors, etc.).

6.2.2 Long stemmed funnels.

6.2.3 Kuderna-Danish concentrator or equivalent (Turbo Vap tubes, etc.).

6.2.4 10mL graduated disposable pipettes or equivalent.

6.2.5 Graduated cylinders - 50mL & 100mL.

6.2.6 Graduated centrifuge tubes or equivalent - 10mL or 15mL.

6.2.7 Autosampler vials or extract containers.

6.1.8 Syringes - 10, 25, 100, 500, and 1000µL.

6.3 Reagents

6.3.1 Methylene chloride - analytical grade or better, must be demonstrated to be below method detection limits for diesel and residual range contaminants.

6.3.2 n-Hexane - analytical grade or better, must be demonstrated to be below method detection limits for diesel and residual range contaminants.

6.3.3 Ottawa sand - cleaned beach sand used for soil method blanks.

6.3.4 Sodium sulfate - Anhydrous, granulated, used for drying soil samples and all methylene chloride extracts.

6.3.5 Silica gel - Anhydrous, 60 - 100 mesh has been used successfully. Prepacked extraction cartridges may be used provided they meet the quality control performance criteria listed in this document.

IMPORTANT: silica gel should be activated by placing in a 150°C oven prior to use, prolonged exposure to moist air will cause high surrogate breakthrough in samples, method blanks, laboratory control samples, and matrix spikes.

6.3.6 Glass wool - Pesticide grade or better.

6.4 Standards

6.4.1 Retention time marker - shall consist of a minimum of n-C_{10} (required only if used in conjunction with DRO analysis), n-C_{25}, and n-C_{36}. More n-alkanes are recommended. This mixture is typically injected into the GC at a concentration of 50µg/mL for each compound.

6.4.2 Initial calibration mixtures: Since it is impractical and nearly impossible to use a commercial residual range distillate for calibration a synthetic mixture must be used. The use of a Flame Ionization Detector or other "carbon counting" detector allows a free association between fuel-derived hydrocarbon compounds providing little or no injector discrimination is present.

Choose a minimum of three -- recommend five or more -- which span the entire residual range. The concentration of the standard is the total of all the individual compounds.

Each compound should be in the same concentration as the others in solution. A minimum of five dilutions of this mixture must be used for calibration purposes. The lowest concentration standard shall be within a factor of three to five of the method detection limit or at the reporting limit, whichever is lower. The highest concentration shall define the upper limit to the calibration. Sample extracts that contain concentrations higher than the calibration curve shall be diluted and reanalyzed.

6.4.2.1 Aromatic - A minimum of three aromatic compounds, which span the residual range, should be used for calibration purposes. Polynuclear aromatic hydrocarbons (PAHs) and their homologues generally suit the purpose of this calibration.

6.4.2.2 Aliphatic - A minimum of three aliphatic compounds, which span the residual range, should be used for calibration purposes. N-alkanes: C_{26}, C_{28}, C_{30}, C_{32}, and C_{34} have been successfully used.

6.4.3 Calibration verification mixture - A synthetic blend of compounds which elute in the residual range is recommended. Any hydrocarbon mixture where more than 95% of the hydrocarbon elutes in the residual range and is independent of the initial calibration may be used.

6.4.4 Continuing Calibration mixture - A mid-level standard using the same or similar compounds used in the initial calibration mixture should be prepared for this purpose.

6.4.5 Surrogate standard mixture - A surrogate mixture shall be made in methylene chloride and shall contain compounds from the three major fractions present in most samples -- aliphatic, aromatic, and polar. Working standards should be prepared to yield a concentration of 100µg/mL of the proper surrogate in the each of the final fractions.

6.4.5.1 Squalane has been successfully used for the aliphatic surrogate; although it elutes in the residual range no problems have been observed.

6.4.5.2 o-Terphenyl has been used as an aromatic surrogate with great success; few interference problems have been observed.

6.4.5.3 Tetrahydronaphthol has been successfully used as a polar surrogate to monitor the elution of polar compounds with the aromatic fraction.

Note: The surrogate standard mixture shall be made up in methylene

chloride or hexane, NOT methanol or acetone, even small amounts of these solvents greatly affect the polarity of the final solutions and will be detrimental to the fractionation.

6.4.6 Internal standard mixture (optional) - 5-α-Androstane may be used as an optional internal standard if deemed necessary by the analyst.

6.4.7 Laboratory control sample / matrix spike mixture - A mixture of aromatic and aliphatic compounds -- a minimum of three each -- shall be used as a laboratory control sample / matrix spike mixture. The mixture shall contain both aromatic and aliphatic compounds and have a concentration sufficient such that a final concentration in each extract fraction is 50µg/mL of each component. For example, if five aromatics and five aliphatics are used then the final concentration of each fraction should be 250µg/mL.

Note: The laboratory control sample / matrix spike mixture must be made up in methylene chloride or hexane, NOT methanol or acetone, even small amounts of these solvents greatly affect the polarity of the final solutions and will be detrimental to the fractionation.

7 Sample Collection, Preservation, and Handling

7.1 Aqueous samples are collected in 1-liter amber glass bottles with Teflon-lined screw caps.

7.2 Soil and sediment samples are collected in 4 oz. (120 mL) amber wide-mouth glass jars with Teflon-lined screw caps.

7.3 Aqueous samples must be preserved at the time of sampling by the addition of a suitable acid to reduce the pH of the sample to less than 2.0. This may be accomplished by the addition of 5 mL of 1:1 HCl to a 1 liter sample. The use of alternative acids is permissible. Following collection and addition of acid, the sample must be cooled to 4°C.

7.4 Soil and sediment samples must be cooled to 4°C immediately after collection.

7.5 A chain of custody form must accompany all aqueous, soil and sediment samples, documenting the time and date of sampling and any preservative additions.

7.6 Aqueous samples must be extracted within 7 days of collection, and analyzed within 40 days of extraction.

7.7 Soil and sediment samples must be extracted within 14 days of collection, and analyzed within 40 days of extraction.

8 Procedure

8.1 Sample Preparation - Samples are extracted using methylene chloride, and, later, solvent-exchanged into hexane. An acceptable extraction procedure for water samples is a separatory funnel liquid/liquid extraction technique based upon SW-846 Method 3510A; continuous liquid/liquid extraction has also proven effective. For soil or sediment samples, use of a Soxhlet or Soxtec technique is recommended. Alternative

extraction procedures are acceptable, provided that the laboratory can document acceptable performance.

8.1.1 Water Extraction

8.1.1.1 Mark the meniscus on the 1-liter sample bottle (for later volume determination) and transfer it to a 2-liter separatory funnel. For blanks and quality control samples, pour 1 liter of reagent water into the separatory funnel. Check the pH of the sample with wide-range pH paper. Note the pH in a laboratory logbook or preparatory sheet.

The pH of the sample need not be adjusted.

8.1.1.2 Add 1.0 mL of the surrogate spiking solution to all samples, blanks, laboratory control samples, and matrix spikes. For samples selected for spiking, add laboratory control sample / matrix spike solution.

8.1.1.3 Add 60mL methylene chloride to the sample bottle to rinse the inner walls of the container and add this solvent to the separatory funnel.

8.1.1.4 Seal and shake each separatory funnel vigorously for 2 minutes with periodic venting to release excess pressure.

NOTE: Methylene chloride creates excessive pressure very rapidly; therefore, venting into a hood should be done immediately after the separatory funnel has been sealed and shaken once.

8.1.1.5 Allow the organic layer to separate from the water phase for a minimum of 10 minutes. If the emulsion interface between layers is more than one-third the size of the solvent layer, the analyst must employ mechanical techniques to complete the phase fractionation. The optimum technique depends upon the sample and may include stirring, filtration of the emulsion through glass wool, centrifugation, or other physical methods.

8.1.1.6 Prepare a filtration apparatus by suspending a funnel with either filter paper or a plug of glass wool and bed of sodium sulfate over a receiving vessel (a Kuderna-Danish vessel or Turbo-Vap tube).

8.1.1.7 Pour organic extract through the sodium sulfate bed and allow to drain into the receiving vessel. Be sure to rinse sodium sulfate thoroughly with methylene chloride after it has drained.

8.1.1.8 Repeat the extraction two more times using additional 60 mL portions of solvent. Combine the three solvent extracts in a 250-mL Erlenmeyer flask. (Steps 8.1.1.3 to 8.1.1.5)

8.1.1.9 For sample volume determination, add water to the sample bottle to the level of the meniscus previously marked, then transfer this water to a graduated cylinder.

8.1.2 Soil Extraction using ultrasonic probe

8.1.2.1 Weigh approximately 25g of soil into a 250mL beaker.

8.1.2.2 Add surrogate standard solution to all samples, blanks, laboratory control samples, and matrix spikes. Add laboratory control sample / matrix spike mixture to appropriate samples.

8.1.2.2 Mix anhydrous sodium sulfate into soil using a metal spatula. This should be done until the soil / sodium sulfate mixture has the consistency of beach sand.

8.1.2.3 Add approximately 60mL of methylene chloride until solids have been covered to a depth of about ½ inch.

8.1.2.4 Place mixture under ultrasound horn and start sonication for two minutes.

8.1.2.5 Prepare a filtration apparatus by suspending a funnel with either filter paper or a plug of glass wool and bed of sodium sulfate over a receiving vessel (a Kuderna-Danish vessel or Turbo-Vap tube).

8.1.2.6 When sonication has finished, pour the solvent through the sodium sulfate bed and allow to drain into the receiving vessel. Be sure to rinse sodium sulfate thoroughly with methylene chloride after it had drained.

8.1.2.7 Repeat steps 8.1.2.3 - 8.1.2.6 two more times.

8.1.2.8 Go to sample concentration and solvent exchange step.

8.1.3 Extract concentration and solvent exchange

8.1.3.1 Using concentration apparatus, concentrate sample until its volume is less than 3mL.

8.1.3.2 Add nonpolar solvent (n-hexane); be sure to thoroughly mix the solution since methylene chloride may tend to stay at the bottom of the container.

8.1.3.3 Concentrate extract down to 5mL.

8.2 Aromatic / Aliphatic Fractionation

8.2.1 Cut the top off a 10mL disposable volumetric Pasteur pipette using a triangular file.

8.2.2 Place a small plug of glass wool into the pipette and slide it down into the taper.

8.2.3 Add a few grams of Ottawa sand to cover the glass wool and provide a flat bed for the silica gel.

8.2.4 Add silica gel to the pipette, with occasional shaking to ensure uniform packing, up to the 3mL mark.

8.2.5 Add another few grams of Ottawa sand to provide some protection to the silica gel bed.

8.2.6 Note the mark where the top of the silica gel is. Add n-hexane to the pipette up to one of the marks on the pipette where the analyst can track the volume of hexane.

8.2.7 When hexane begins to drip out the bottom of the pipette, note the volume of hexane added to the top and the volume left. This will be the column volume. Allow one more column volume to pass through to rinse the silica gel and discard the hexane.

8.2.8 When the hexane level has reached the top of the sand, add 1.0mL of hexane extract. Allow this to flow down into the sand before adding more hexane. Begin collecting hexane in graduated 15mL-centrifuge tube or volumetric Kuderna-Danish tube when ½ to ¾ of a column volume of hexane has passed through the column.

8.2.9 Each solvent wash should consist of 1.5 to 2.5 column volumes to eliminate break through. With experience, the analyst should be able to determine the amount of wash needed.

8.2.10 When the hexane level has dropped into the sand, slowly add pure methylene chloride to the top of the column.

8.2.11 When ½ to ¾ of a column wash of methylene chloride has passed through the silica gel, change collection tubes and mark the hexane fraction as Aliphatic.

8.2.12 Continue adding methylene chloride until 1.5 to 2.5 volumes have passed.

8.2.13 If the polar compounds are of interest, add a third wash of 5 - 10% methanol in methylene chloride. Otherwise, finish the methylene chloride wash with one additional column volume. Remove this fraction and label it Aromatic.

Note: The amount of solvent in each receiver should be approximately the same as the calculated column volume times the multiplication factor in use for the lab (1.5 to 2.5).

Note: Column overloading is a common occurrence. Dilution of samples prior to fractionation may be necessary to avoid unwanted breakthrough.

8.2.14 Using an appropriate concentration device, concentrate each fraction down to 1.0mL. If internal standard is used, add it now. Samples are ready for analysis.

8.3 Analysis

8.3.1 Gas Chromatograph Conditions (Recommended)

Parameter	Setting
Gas	Helium
Linear velocity	60 - 65cm/s

Initial Temp.	35°C
Initial Time	4min.
Rate	15°C/min.
Final Temp.	250°C
Hold	0min.
Rate II	25°C/min.
Final Temp. II	350°C
Hold II	5 - 10min.
Injector Temp.	310°C; Note: higher temperatures cause thermal cracking of hydrocarbons.
Detector Temp.	355°C

8.3.2 Gas Chromatograph Sequencing - The GC sequence must include a 24 hour retention time marker, a continuing calibration standard for every 10 injections -- that is, a beginning continuing calibration standard, and one after each subsequent 10 injections -- and an ending continuing calibration standard. Each sample batch should be analyzed in one sequence on the same instrument.

8.3.3 Calibration - A minimum of 5 concentrations of standard must be used to define the calibration curve. The concentration of each standard is the total of the concentrations of analytes present in that standard, hence, 5 analytes at 50µg/mL has a total concentration of 250µg/mL.

8.3.3.1 The lowest standard shall be equivalent to the reporting limit or a value three to five times the method detection limit, whichever is lower.

8.3.3.2 The highest concentration standard shall define the highest extract concentration that may be reported without dilution.

8.3.3.3 Whenever possible, use a least squares linear regression for calibration. Quadratic curves and average of response factors are acceptable provided adequate quality control and performance parameters are consistently met.

9 Calculations

9.1 Response Factors

$$Response\,Factor = \frac{(Area_{x,std})}{(C_{x,std})} \qquad \text{Eq. 1}$$

Where

$A_{x,std}$ = Area of analyte in standard.
$C_{x,std}$ = Concentration of analyte in Standard in µg/mL.

9.2 Concentrations

9.2.1 Soil External Standard (example) – many software packages will report concentrations of extracts without any problem. The following is for those cases where this is not done. It requires an average of response factors.

$$Concentration\ in\ Soil(mg/Kg) = \frac{(Area_x)(df)(V_f)(1000\mu g/mg)}{(rf)(m_f)(W_i)} \quad \text{Eq. 2}$$

Where

A_x = Area of analyte in extract.
df = Dilution Factor of extract.
V_f = Final volume of extract after concentration step.
rf = Response factor.
m_f = Fractional dry mass (% Dryness)
W_i = Initial Weight of soil sample.

Note: If instrument reports concentration in extract; that value can replace the ($Area_x$/rf) portion of the equation.

9.2.2 Water External Standard (example) – many software packages will report concentrations of extracts without any problem. The following is for those cases where this is not done. It requires an average of response factors.

$$Concentration\ in\ Water(\mu g/L) = \frac{(Area_x)(df)(V_f)}{(rf)(V_i)} \quad \text{Eq. 3}$$

Where

A_x = Area of analyte in extract.
df = Dilution Factor of extract.
V_f = Final volume of extract after concentration step.
rf = Response factor.
V_i = Initial volume of water (aqueous) sample.

Note: If instrument reports concentration in extract; that value can replace the

($Area_x$/rf) portion of the equation.

9.3 Fractional Mass of a soil – This is the fractional version of %Dryness for use in soil calculations.

$$Fractional\ Mass = \frac{(m_d)}{(m_s)} \qquad \text{Eq. 4}$$

Where

m_d = Weight of dried soil.
m_s = Weight of sample before drying.

9.4 Relative Percent Difference

$$RPD = \frac{(X_1 - X_2)}{(X_1 + X_2)/2} * 100\% \qquad \text{Eq. 5}$$

10 Quality Control

10.1 Retention Time Markers

10.1.5 A retention time marker must be analyzed at least once every 24-hour period or once each day of instrument operation.

10.1.6 The analyst must use the retention times for the ranges of interest from three separate retention time markers to determine acceptable retention time variation.

10.1.7 If the retention time of a retention time marker standard falls outside the established window, the retention time must be updated and a new retention time window established.

10.2 Initial Calibration – A minimum five-point calibration must be performed to establish the working range of the Gas Chromatograph.

10.2.1 An initial calibration must be made up for each fraction – aromatic and aliphatic – and must contain a minimum of three compounds.

10.2.2 The initial calibration should contain hydrocarbons representative of the particular fraction to be analyzed.

10.2.3 The lowest concentration must be between 3 and 5 times the method detection limit concentration or at the reporting limit concentration, whichever is lower.

10.2.4 The highest concentration will define the upper limit concentration that

may be reported without extract dilution.

10.2.5 If a linear regression is used (recommended), the coefficient of correlation must be 0.98 or higher.

10.2.6 If an average of response factors is used, the maximum %RSD must be no greater than 15%.

10.2.7 A quadratic calibration may be used if the GC software allows this type of calibration. The coefficient of correlation must not fall below 0.98.

10.2.8 All data points in the calibration should be weighted equally.

10.2.9 Corrective Actions

a) If the initial calibration is outside the control limits, analysis shall not be performed.
b) Reintegrate all standards.
c) Prepare and reanalyze a new curve.

10.3 Second Source Calibration Verification – A standard used to verify the initial calibration.

10.3.1 The second source calibration verification may be made up from a standard similar to the initial calibration at an intermediate level.

10.3.2 The second source compounds must be obtained from a separate source than the initial calibration compounds.

10.3.3 A residual range distillate may be used in the place of a synthetic calibration standard provided more than 95% of the hydrocarbon area elutes within the ADEC defined residual range.

10.3.4 The second source calibration verification standard may also be used as the continuing calibration standard.

10.3.5 The recovery of the second source calibration verification must be +/- 15% of the true value.

10.3.6 Corrective Actions

a) If the second source verification standard is outside the control limits, analysis shall not be performed.
b) Reanalyze the second source calibration verification standard.
c) Reprepare a new standard.
d) Reprepare and analyze a new initial calibration.

10.4 Instrument Blank

10.4.1 Must be below reporting limits before proceeding with further analysis.

10.4.2 Must be analyzed at least once every 24 hours of instrument operation or when a sample when instrument carryover is suspected.

10.4.3 An instrument blank is recommended after samples high in concentration.

10.4.4 Corrective Actions

a) If an instrument blank is outside the limits, all samples associated with that blank must be reanalyzed.

10.5 Continuing Calibration Standard

10.5.1 The Continuing Calibration Standard may be made up from a standard similar to the initial calibration at an intermediate level.

10.5.2 A residual range distillate may not be used in the place of a synthetic calibration standard since more than 95% of the hydrocarbon area of any known distillate will elute within the ADEC defined residual range.

10.5.3 The continuing calibration standard may also be used as the second source calibration verification.

10.5.4 The recovery of the second source calibration verification must be +/- 15% of the true value.

10.5.6 A continuing calibration standard must be analyzed at the beginning of an analytical run, once every 10 injections on the GC, and at the close of the run.

10.5.7 Corrective Actions

a) If a Continuing Calibration Verification is outside the limits, all samples associated with that standard must be reanalyzed.
b) Be certain Continuing Calibration Verification is fresh and within limits.

10.6 Method Blank

10.6.1 The method blank must be made up from a matrix similar to the samples within the analytical batch (e.g. water for aqueous, sand for sandy soil, clean loam for mossy high biomass samples)

10.6.2 Surrogate standards must be added to all method blanks and must fall within the window of 70 – 120% of the true values.

10.6.3 The method blank must be free of contamination (below reporting limits) within the specified range.

10.6.4 Corrective actions

a) Reanalyze method blank being sure no instrument carryover is present.
b) If problem persists, or surrogates are outside acceptable ranges, associated analytical batch must be re-extracted and analyzed.

10.7 Laboratory Control Sample and Laboratory Control Sample Duplicate (LCS/LCSD).

10.7.1 The LCS/LCSD/Matrix Spike working standard must be made up of a synthetic mixture of analytes. A minimum of three aromatic and three aliphatic compounds must be used for each range (DRO, RRO, and GRO).

10.7.2 The LCS/LCSD should be made up from a matrix similar to the samples within the analytical batch (e.g. water for aqueous, sand for sandy soil, clean loam for mossy high biomass samples).

10.7.3 Surrogate standards must be added to all LCS/LCSD and must fall within the window of 70 – 120% of the true values.

10.7.4 Matrix spike/LCS compounds must be added to all LCS/LCSD samples and must fall within the window of 70 – 120% of the true values.

10.7.5 Compounds from the other fraction must not exceed 10% (e.g. the aliphatic LCS/LCSD samples may not have more than 10% recovery of any single aromatic LCS/LCSD/Matrix Spike compound or visa versa).

10.7.6 The duplicate must have a relative percent difference of less than 20%.

10.7.7 Corrective actions

a) Reanalyze LCS/LCSD being sure no instrument carryover is present.
b) If problem persists, or surrogates are outside acceptable ranges, associated analytical batch must be re-extracted, re-fractionated and/or re-analyzed.

10.8 Matrix Spike (MS)

10.8.1 The LCS/LCSD/Matrix Spike working standard must be made up of a synthetic mixture of analytes. A minimum of three aromatic and three aliphatic compounds must be used for each range (DRO, RRO, and GRO).

10.8.2 The matrix spike must be made up from a sample within the analytical batch.

10.8.3 Surrogate standards must be added to all matrix spike samples and should fall within the window of 50 - 150% of the true values.

10.8.4 Matrix spiking/LCS compounds must be added to all matrix spike samples and should fall within the window of 50 - 150% of the true values.

10.8.5 Compounds from the other fraction must not exceed 10% recovery (e.g. the aliphatic matrix spike samples may not have more than 10% recovery of any single aromatic LCS/LCSD/Matrix Spiking compound or visa versa).

10.8.6 Corrective actions

No corrective actions are required for a matrix spike that is out of compliance.

10.9 Surrogate Spikes

10.9.1 At least one aromatic and one aliphatic surrogate compound which does not coelute or otherwise interfere with the analytes of interest must be added to each sample, method blank, LCS/LCSD, and matrix spike.

10.9.2 Since diesel and residual range compounds are often analyzed together, the compounds one compound per fraction will suffice for the modified AK102AA/103AA combined method.

10.9.3 The recovery of surrogate standards must not be outside the range 70 – 120% for method blanks and LCS/LCSD samples.

10.9.4 The recovery of surrogate standards should not be outside the range 50 - 150% for all remaining samples and matrix spikes.

10.9.5 Surrogate compounds from the other fraction must not exceed 10% recovery in a given fraction (e.g. the aliphatic samples or matrix spikes may not have more than 10% recovery of any single aromatic surrogate compound or visa versa).

10.9.6 The polar surrogate shall not be observed above 10% recovery in any sample, method blank, LCS/LCSD, or matrix spike.

10.9.7 Corrective Actions

a) If the surrogates for a sample are out of limits, that sample must be re-extracted, re-fractionated, and/or re-analyzed.
b) If a surrogate is out of limits in the same direction (e.g. low both times) for a second time, the report shall reflect a matrix effect.
c) If a surrogate is higher than limits for the opposing fraction, that sample shall be re-extracted, re-fractionated, and/or re-analyzed. Care must be taken to ensure the quality and the activity of the silica gel or alumina or other adsorptive material in the fractionation column.
d) If a surrogate compound is out of limits for a method blank or LCS/LCSD sample, that sample must first be re-analyzed; then, if still out, the entire analytical batch must be re-extracted, re-fractionated, and re-analyzed.

11 References

11.1 Alaska Department of Environmental Conservation, Methods AK102 & AK103.

11.2 The Federal Register, 62 FR 52098, Oct 1997.

11.3 Massachusetts Department of Environmental Protection and ABB Environmental Services, Inc., Wakefield, MA "Interim Petroleum Policy: Development of Health-based Alternative to the Total Petroleum Hydrocarbon (TPH) Parameter", August 1994.

11.4 USEPA, "Measurement of Petroleum Hydrocarbons: Report on Activities to Develop a Manual" Prepared by Midwest Research Institute, Falls Church, VA, under EPA Contract #68-WO-0015, WA No. 4; submitted to USEPA Office of Underground Storage Tanks, Washington, DC; November 20, 1990.

11.5 USEPA Regulations 40 C.F.R. 136, Appendix B, "Guidelines Establishing Test procedures for the Analysis of Pollutants", July 1992.

11.6 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 3510: Separatory Funnel Liquid-Liquid Extraction; September 1986.

11.7 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 3540: Soxhlet Extraction; September 1986

11.8 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 3630: Silica Gel Cleanup; September 1986

11.9 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 8000: Gas Chromatography; September 1986

11.10 USEPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Method 8100: Polynuclear Aromatic Hydrocarbons; September 1986

11.11 Wisconsin Department of Natural Resources, "Modified DRO - Method for Determining Diesel Range Organics", PUBL-SW-141, 1992

11.12 USEPA, "Guidance on Evaluation, Resolution, and Documentation of Analytical Problems Associated with Compliance Monitoring", EPA 821-B-93-001; U.S. Government Printing Office, Washington D.C., June, 1993

APPENDIX E

Alaska Department of Environmental Conservation
Hazard Ranking Evaluation Form

Purpose of this form
This form is used only for sites with underground storage tanks that are subject to regulation under AS 46.03.365. The form is based on the "Alaska Hazard Ranking Model" which ADEC uses to prioritize its investigation and cleanup efforts. It is used to collect preliminary information on the relative risk a contaminated site may pose to human health and the environment.

Explanation of how sites are scored
The box below explains how a site will be scored after ADEC receives this form. Note that although the form contains values for "unknown" elements, a minimum combination of the following data elements are needed for adequately distinguishing between sites: toxicity, quantity, air exposure, ground water exposure, and surface water exposure. Also note that scores cannot be calculated in the following instances:

1. If too many data elements are unknown; or,
2. If both the toxicity and the quantity data elements are unknown; or,
3. If all exposure elements are unknown.

Scoring procedure for risk evaluation Form
The Preliminary Risk Evaluation Form contains 14 different questions. Each question deals with a particular "data element" (shown below) that is considered in scoring the site. The alternatives to each question are assigned a value and then these values are entered into the formulas below to calculate the final score.

Question #	Data Element
1.	Toxicity
2.	Quantity
3.	Release Information
4.	Site Access
5.	Air Exposure
6a.	Population Density (within one mile)
6b.	Population Proximity (500 feet)
7.	Ground Water Usage
8.	Ground Water Exposure
9.	Surface Water Use
10.	Surface Water Exposure
11.	Surface Water Environment
12.	Environmental/Recreational Area
13.	Observed Environmental Impact
14.	Multiple Sources or Contaminants

Scoring

Ranking Score = Substance Factor x (Human Target + Environmental Target)

Substance Factor = (#1) x (#2) x (#3)

Human Target = (#4 + Air Target Population + Adj. Ground Water Use + Adj. Surface Water Use)
Air Target Population = (#5) x (# 6a) x #(6b)
Adj. Ground Water Use = (#7) x (#8) x (#6a)
Adj. Surface Water Use = (#9) x (#10) x (#6a)

Environmental Target = (#11) + (#12)
or, if (#11) + (#12) = 0, use value in (#13)

If there are **multiple contaminants** (answer is "yes" to #14), multiply Ranking Score by 1.2.
(Numbers in parentheses refer to the 14 "data elements" identified above.)

Return completed form to: ADEC Underground Storage Tank Section
555 Cordova Street, Anchorage, Alaska 99501-2617
Telephone: (907) 269-7503 FAX (907) 269-7649

ADEC Hazard Ranking Evaluation Form

Please type, or print in ink, all the requested information on this page.

General Information

Name of Site: _____

Facility ID Number: _____

Tax ID Number: _____

Applicant:

Name: _____
Address: _____
_____
_____
Telephone: _____

Facility:

Name: _____
Address: _____
_____
_____
Telephone: _____

Owner of Tank (if not the same as applicant):

Name: _____
Address: _____
_____
_____
Telephone: _____

Owner of Land (if not the same as applicant):

Name: _____
Address: _____
_____
_____
Telephone: _____

Preparer:

Name: _____
Title: _____
Firm: _____
Telephone: _____

Please provide any additional information that may assist in processing the Preliminary Risk Evaluation Form (i.e. directions to the site if it does not have a physical address, uncertainties over how to answer particular questions, etc.). Please use additional pages, if necessary.

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HAZID #

ADEC Hazard Ranking Evaluation Form

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(Values for scoring are in parentheses following each option)
On pages 3-6, please fill in the letter of the correct choice in the box preceding each question

1__ ☐ 1. **What type of product was released or detected?**

If more than one substance is present, use the one that will score the highest substance factor.

a. Chlorinated solvents, other halogenated hydrocarbons, synthetic chlorinated organic pesticides. (4)
b. Metals, gasoline, aviation gas, naphtha, non-chlorinated pesticides. (3)
c. Unknown substances. (2.1)
d. Diesel fuel, jet fuels, (JP-4, JP-5), kerosene, non-chlorinated phenols, non-chlorinated solvents, crude oil. (2)
e. Waste lubricating oils, heavy fuel oils (No. 6, etc.), inorganic acids/bases, tar. (1)

2.__ ☐ 2. **What quantity of product was released?**

a. < 10 drums or 549 drum or tank gallons, < 500 spilled gallons, < 100 cubic yards or tons, < 100 ft^2. (1)
b. 10-99 drums or 550 - 5,499 drum or tank gallons, 500 - 9,999 spilled gallons, 100 - 499 cubic yeards or tons, 100 - 9,999 ft^2. (2)
c. Unknown quanity. (2.1)
d. 100 - 999 drums or 5,500 - 54,999 drum or tank gallons, 10,000 - 39,999 spilled gallons, 500 - 1,999 cubic yards or tons, 10,000 - 43,559 ft^2. (3)
e. >/= 1,000 drums or >/= 50,000 drum or tank gallons, >/= 40,000 spilled gallons, >/= 2,000 cubic yards or tons, >/= 1 acre (43,560 ft^2). (4)

Note: *<means "less than" (i.e. 1 <10, or one is less than ten)*
>means "greater than" (i.e. 10 > 1, or 10 is greater than one)
>/= means "greater than or equal to" (i.e. 11 >/= 10, or 11 is greater than or equal to 10)

3.__ ☐ 3. **Has a release at the site been documented?**

a. Documented releases indicate contamination due to disposal practices or failure of containment at the site, regardless of quantity. (1)
b. Containment management practices exist which may pose a significant threat, but there is no documentation of a release. (.5)
c. An unknown potential for site release exists, or off-site contamination is not clearly linked to the site. (.2)
d. There is a documented absence of a release at the site. (.1)

4.__ ☐ 4. **How controlled is access to this site?**

a. A school is present within 500 feet, and, site access is partially controlled or uncontrolled, and, wastes are present at the surface. (3)
b. Access to the site is uncontrolled, and, wastes are present at the surface. (2)
c. Access to the site is partially controlled, or, surrounding features restrict site access, or , contaminated soil is stockpiled (presumed covered) on site. (1)
d. There is an underground tank, or waste is not present at the surface, or access to the site is completely controlled. (0)

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5.___

☐ 5. **Have contaminants been released to the atmosphere?**

a. A documented release of particulate or gases from the site has been confirmed. (1)
b. A release may have occurred at the site based on existing physical evidence, including uncovered stockpiles of excavated soils. (.2)
c. No significant air releases have been identified at the site and waste management practices indicate no substantial possibility. (.1)

6a.___

☐ 6a . **What is the predominant population density within 1 mile radius?**

a. Urban residential use (in or adjacent to population > 35,000, single family lots < 1/4 acre). (10)
b. Suburban residential areas (lots 1/4 - 1 acre), or, cities with population between 2,000 - 35,000, or, industrial/commercial areas. (8)
c. Villages (<2,000 people), or, low density housing (one unit per acre), or, low density commercial use, or, few permanent residents, but intensive seasonal use. (5)
d. Rural use, with some occupied buildings. No villages or associated commercial/industrial areas within 1 mile (3)
e. Isolated areas with no population present. (0)

6b.___

☐ 6b. **What is the predominant population in proximity to the site (within 500 feet)?**
(Also count workers at site, residents of military barracks or lodges, and students at a school.)

a. Occupied buildings or dwellings present within 500 feet of site. (1)
b. No occupied buildings within 500 feet. (0.5)

7.___

☐ 7. **What is the ground water usage within 1 mile?**

a. Within a 1 mile radius, a majority of the population is served by municipal wells or other public water supply wells serving > 25 individuals. (1)
b. Within a 1 mile radius, a majority of the population is served primarily by community or private wells. (.8)
c. A majority of the population is served by drinking water supplies originating greater than a mile from the site, but other public water supply wells serving more than 25 individuals are located within one mile of the site. (.6)
d. A majority of the population is served by drinking water supplies that are > 1 mile from the site, or there are no known wells within one mile, but the possibility of use of drinking water exists. (.4)
e. Ground water as a source of drinking water or is not used. (.1)

8.___

☐ 8. **Has there been any documentation of ground water contamination?**

a. Documented contamination of a drinking water supply at the tap exceeds the MCL. (4)
b. Documented contamination of a drinking water supply at the tap, does not exceed the MCL. (2)
c. Ground water contamination has been detected but actual contamination at the tap has not been documented. (1)
d. Ground water contamination is unknown, either at the tap or at the ground water source. (.4)
e. Ground water is documented to be free of contamination, or, waste and site characteristics indicate a low potential for contamination. (0)

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9. **What is the primary use of surface water within 1 mile?**

a. Surface water is used as a drinking water source supplied by intakes within 1 mile of site. *Assign this value if surface drinking water supplies within one mile of the site have been abandoned due to site contamination.* (1)
b. Use of surface water as a source of drinking water, from intakes within 1 mile, is unknown, but likely. (.5)
c. Use of surface water as a source of drinking water is unknown but is unlikely, or, there is no use of surface water as a drinking water source within a 1 mile radius. (.2)

10.

10. **Has surface water been contaminated by a release from the site?**

a. Documented contamination of surface drinking water supply at the tap, exceeds the MCL due to releases of hazardous material from the site. (4)
b. Documented contamination of surface drinking water supply at the tap does not exceed the MCL. (2)
c. Surface water contamination has been detected at a drinking water source, but actual contamination of drinking water supply at the tap has not been documented. (1)
d. Surface water contamination is unknown. (4)
e. Surface water is not used as a source of drinking water, or , surface water is documented to be free of contamination, or site and waste characteristics indicate a low potential for contamination of surface water. (0)

11.

11. **What type of surface water environment exists within 1/4 mile of the site?**

a. Fresh or marine water or wetlands are present within 1/4 mile, and evidence of death or stress to fish or wildlife exists, which is strongly suspected as a result of the presence of hazardous substances. (5)
b. Fresh or marine waters or wetlands are present within 1/4 mile, and evidence of death or stress to plants exists, which is strongly suspected as a result of the presence of hazardous substances. (3)
c. Fresh or marine waters or wetlands are present within 1/4 mile, but there is no evidence of death or stress to fish, wildlife, or plants. (2)
d. No fresh or marine waters or wetlands are present within 1/4 mile. (0)

12.

12. **Is the site in an environmental/recreation area?**

a. The site is in an environmental/recreation area and evidence exists of death or stress to fish or wildlife, which is strongly supsected as a result of the presence of hazardous substances. (5)
b. The site is an environmental/recreation area and evidence exists of death or stress to plants, which is strongly suspected as a result of the presence of hazardous substances. (3)
c. The site is in an environmental/recreation area and there is no evidence of death or stress to fish, wildlife, or plants. (2)
d. The site is not in an environmental/recreation area. (0)

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13.___

14.___

If your answer to both questions 11 and 12 was "d", and there are documented impacts to the environment which are not within 1/4 mile of surface waters or located within 1/4 mile of an environmental or recreation area, then proceed to question number 13. Otherwise, skip 13, and proceed to question 14.

☐ 13. **What are the observed environmental impacts to surface waters not within 1/4 mile, or which are not within environmental/recreational areas?**

a. There is evidence of death or stress to fish or wildlife, which is strongly suspected as a result of the presence of hazardous substances. (5)

b. There is evidence of death or stress to plant life, which is strongly suspected as a result of the presence of hazardous substances. (3)

c. There is no evidence of death or stress to wildlife or plant life. (0)

☐ 14. **Are there multiple sources of contamination present at the site? Yes or No**
(A yes answer will result in the final score being multiplied by 1.2, otherwise there will be no adjustment to the final score.)

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Scores assigned by:_____