FINAL
DEVELOPMENT OF RISK-BASED CLEANUP LEVELS FOR PETROLEUM HYDROCARBONS MEASURED AS DRO AND GRO

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Prepared for:

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GLOSSARY OF ACRONYMS

BTEX	Benzene, Ethylbenzene, Toluene, Xylene
CPAH	Carcinogenic Polynuclear Aromatic Hydrocarbon
DRO	Diesel Range Organics
ELCD	Electrolytic Conductivity Detector
EPC	Exposure Point Concentration
EPH	Extractable Petroleum Hydrocarbon
FID	Flame Ionization Detector
GC	Gas Chromatograph
GRO	Gasoline Range Organics
HETL	Health and Environmental Testing Laboratory
HPLC	High Performance Liquid Chromatography
MassDEP	Massachusetts Department of Environmental Protection
MEDEP	Maine Department of Environmental Protection
MEGS	Maximum Exposure Guidelines
mg/kg	Milligrams per Kilogram
MS	Mass Spectrometer
MTBE	Methyl-Tert-Butyl Ether
PAH	Polynuclear Aromatic Hydrocarbons
PID	Photo Ionization Detector
QA/QC	Quality Assurance/Quality Control
RAGs	Remedial Action Guidelines
RfD	Reference Dose
SIM	Selective Ion Monitoring
SVOCs	Semi-volatile Organic Compounds
TAL	Target Analyte List
TPH	Total Petroleum Hydrocarbon
USEPA	U.S. Environmental Protection Agency
UST	Underground Storage Tank
UV	Ultraviolet
VOCs	Volatile Organic Compounds
VPH	Volatile Petroleum Hydrocarbon

1.0 INTRODUCTION

Until December of 2009, Maine Department of Environmental Protection's (MEDEP) guidance for petroleum site cleanup recommended using Diesel Range Organics (DRO) and Gasoline Range Organics (GRO) analytical approaches. Then, in December of 2009, the MEDEP published "Remediation Guidelines for Petroleum Contaminated Sites in Maine" (MEDEP, 2009a). These new cleanup guidelines call for Volatile Petroleum Hydrocarbon (VPH) and Extractable Petroleum Hydrocarbon (EPH) analysis, rather than GRO and DRO. The purpose of this guidance is to approximate whether the new EPH and/or VPH cleanup guidelines in soil are met at a site, based on a review of historic DRO and/or GRO soil results.

This report translates the VPH and EPH cleanup guidelines into DRO and GRO cleanup levels for the following petroleum source materials:

- Gasoline
- No. 2 heating oil/diesel
- No. 6 heating oil
- Used crankcase oil
- Stoddard solvent
- Unknown petroleum product

These guidelines are based on protecting public health from direct contact with soil and leaching of soil contaminants to groundwater that serves as a source of drinking water, and do not consider ecological impacts or migration of volatile compounds from soil to indoor air. For weathered products and unknown petroleum product, the GRO/DRO cleanup levels in this document may under- or over-estimate risk, and should be used with caution. Ideally, for weathered and unknown product, the GRO/DRO cleanup levels should only be applied when analytical results for target analyte list (TAL) compounds are also available.

1.1 CONCEPTUAL APPROACH

Petroleum products (e.g., No. 2 heating oil, gasoline, crankcase oil) are composed of hundreds of petroleum hydrocarbon compounds that vary in size (ranging from 5 to more than 50 carbon atoms), structure (alkanes, cycloalkanes, alkenes, and aromatics), and toxicity. The hydrocarbon

compounds with the highest toxicity have been identified by the U.S. Environmental Protection Agency (USEPA) and MEDEP as TAL compounds. TAL compounds include benzene, ethylbenzene, toluene, xylene (BTEX), methyl-tert-butyl ether (MTBE), and sixteen polynuclear aromatic hydrocarbons (PAHs).

TAL compounds generally represent only a small percentage of the total composition of petroleum mixtures. Historically, Maine required evaluation of petroleum contamination using DRO and GRO analytical procedures, which measured the total concentration of petroleum hydrocarbon compounds, because cleanup guidelines were expressed in DRO and GRO. In light of recently developed toxicity information, we now know that the historic guidelines were poorly correlated with health risk. We have come to learn that the specific hydrocarbon structures within a mixture of petroleum hydrocarbons exhibit various orders of toxicity, the mixture varies by product and age, and only by identifying the specific hydrocarbon compounds in the mixture can the toxicity of the product be evaluated and a risk-based level applied.

Fortunately, methods to evaluate the toxicity, and subsequently the health risk, associated with exposures to petroleum hydrocarbon mixtures were developed by other state agencies and Maine was able to adopt these methods into the new guidelines (MEDEP, 2009a). These methods are based on the following conceptual approach:

- It is acknowledged that whereas it is not feasible to quantify the toxicity of each of the hundreds of individual non-TAL compounds in a petroleum hydrocarbon mixture, it is feasible to quantify the toxicity of groups of hydrocarbon compounds that are toxicologically similar. Dose-response values applicable to those hydrocarbon groups can be developed.
- The purpose of evaluating non-TAL hydrocarbons is to quantify the non-cancer toxicity (hazard index) associated with the petroleum mixture, since the majority of any given petroleum hydrocarbon source material is associated with non-TAL parameters and cannot be completely captured by the toxicity and risk associated with the TAL parameters. Cancer toxicity is quantified via evaluation of TAL compounds, notably carcinogenic PAHs and benzene, which represent the principal carcinogenic compounds of interest in petroleum hydrocarbon mixtures. Consequently, when petroleum mixtures that could contain potentially carcinogenic compounds are evaluated, it is necessary to quantify or in some way account for the TAL parameters (carcinogenic PAHs and/or benzene) to capture the carcinogenic risk associated with the petroleum mixture.
- The toxicity associated with hydrocarbons is dependent on the structure and size of the hydrocarbon compound. Aromatic structures tend to exhibit a higher degree of toxicity than aliphatic structures, and toxicity decreases with increasing hydrocarbon size. Hydrocarbon compounds with more than 36 carbon atoms exhibit negligible toxicity.

- Analytical procedures can be used to quantify the concentrations of petroleum hydrocarbon groups, or fractions, by structure (e.g., aliphatic vs. aromatic) and size (e.g., number of carbon atoms in the structure). The analytical procedures can be used to identify the concentrations of hydrocarbon fractions that are of toxicological significance from a risk assessment and site cleanup perspective.
- The quantification of hydrocarbon fractions of interest in a petroleum hydrocarbon mixture can be integrated with dose-response values for the hydrocarbon fractions, and quantitative parameters that describe human exposure to the petroleum-contaminated medium, in a standard risk assessment framework to quantify health risks or derive risk-based cleanup levels for petroleum hydrocarbon mixtures.

MEDEP has developed a framework to evaluate petroleum contamination using a compilation of data for TAL parameters and for hydrocarbon fractions of toxicological significance, with risk-based guidelines developed for EPH and VPH (MEDEP, 2009a). The EPH fractions that are characterized and evaluated using this methodology are C9-C18 aliphatic hydrocarbons, C19-C36 aliphatic hydrocarbons, and C11-C22 aromatic hydrocarbons. The VPH fractions that are characterized and evaluated using this methodology are C5-C8 aliphatic hydrocarbons, C9-C12 aliphatic hydrocarbons, and C9-C10 aromatic hydrocarbons. The approach developed by MEDEP is similar to the approach developed by the Massachusetts Department of Environmental Protection (MassDEP) (described in "Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MassDEP EPH/VPH Approach" (MassDEP, 2002)), and to the approaches developed by other states (e.g., Indiana, Washington). One consequence of the revisions, however, is that there are sites with on-going investigations for which petroleum has been measured using the DRO and GRO analytical methods. To enable the existing body of DRO and GRO analytical data for those sites to be used, this report has been prepared to provide risk-based cleanup levels for petroleum that has been measured as DRO and GRO. The derivation of cleanup levels for DRO and GRO in soil incorporates aspects of the risk-based approach for petroleum that has been implemented by MEDEP (MEDEP, 2009a).

GRO and DRO analyses do not quantify hydrocarbon concentrations in terms of hydrocarbon structures (e.g., aliphatic or aromatic), and are limited to measurement of hydrocarbon compounds that fall within two specific size ranges: GRO measures hydrocarbons in the C5 to C10 range, and DRO measures hydrocarbons in the C10 to C28 range. Conceptually, the GRO analysis would primarily correspond to the C5 – C8 aliphatic and C9 – C10 aromatic fractions, and DRO analysis would primarily correspond to the C9 – C18 aliphatic, C19 – C36 aliphatic, and C11 – C22 aromatic fractions.

Since risk-based concentrations for petroleum hydrocarbons are calculated in recognition of the size and structure of the hydrocarbon compounds, the petroleum hydrocarbon composition of a petroleum product in terms of aliphatic and aromatic hydrocarbon fractions and target analytes must be recognized. In the absence of site-specific analytical data that provides petroleum hydrocarbon composition in terms of aliphatic and aromatic hydrocarbon fractions (as would be obtained using the recent MEDEP guidance (MEDEP, 2009a)), an understanding and/or assumption must be made concerning the composition of the petroleum hydrocarbon source material that is being measured by the DRO and GRO analysis. Therefore, this evaluation uses information from the literature to define the composition of specific petroleum source materials in terms of petroleum hydrocarbon fractions and TAL parameters. The compositional information is used with the risk-based concentrations for the petroleum hydrocarbon fractions and TAL parameters published by MEDEP, to derive risk-based cleanup levels for the petroleum hydrocarbon mixtures that constitute the petroleum source materials evaluated in this report.

1.2 REPORT ORGANIZATION

The technical approach that has been used to derive the risk-based cleanup levels is presented in Section 2. The technical approach that has been used to derive the leaching-based cleanup levels is presented in Section 3. Application of the risk-based cleanup levels using DRO and GRO analytical data, including consideration of analytical chemistry, is discussed in Section 4.

2.0 DERIVATION OF RISK-BASED CLEANUP LEVELS

The technical approach for deriving risk-based cleanup levels involves first identifying risk-based concentrations for individual petroleum hydrocarbon fractions and TAL parameters. The risk-based concentrations are then applied with information concerning the composition of petroleum hydrocarbon mixtures, in terms of the percentages of hydrocarbon fractions and TAL parameters, to derive risk-based cleanup levels for the six petroleum source materials evaluated in this report.

2.1 RISK-BASED CONCENTRATIONS FOR PETROLEUM HYDROCARBON FRACTIONS AND TARGET ANALYTE LIST PARAMETERS

A risk-based concentration is a chemical concentration in a medium (e.g., hydrocarbon concentration in soil) that corresponds to a specified level of health risk (e.g., a hazard index of 1) for a specific set of exposure assumptions. In order to derive risk-based cleanup levels for petroleum hydrocarbon mixtures, risk-based concentrations must first be identified or calculated for each of the hydrocarbon fractions and TAL parameters that are contained in the petroleum mixtures.

MEDEP has derived risk-based guidelines for individual petroleum hydrocarbon fractions as well as TAL parameters in "Remediation Guidelines for Petroleum Contaminated Sites in Maine" (MEDEP, 2009a). The risk-based guidelines were derived using a standard risk assessment three-step process:

1) Identify petroleum hydrocarbon fractions, TAL parameters, and associated dose-response values;
2) Identify land use scenarios for which risk-based concentrations will be derived; and
3) Identify target risk levels and calculate risk-based concentrations.

The technical approach used by MEDEP to implement this three step process and derive risk-based guidelines is provided in Appendix C (Technical Basis and Background for the Maine Petroleum Soil Guidelines) of "Remediation Guidelines for Petroleum Contaminated Sites in Maine" (MEDEP, 2009a). That approach is consistent with the approach used by MEDEP to derive the Maine Remedial Action Guidelines (RAGS) as described in "Technical Basis and Background for the Maine Remedial Action Guidelines" (MEDEP, 2010).

In summary, MEDEP derived risk-based guidelines for soil for four land use scenarios (resident, park user, outdoor commercial worker, and construction worker). The guidelines for each land use scenario accounted for potential exposures to soil by three routes of exposure (incidental soil ingestion, dermal contact, and dust and vapor inhalation). A description of the land use scenarios, as well as the quantitative parameters used to derive risk-based levels, is provided in "Guidance for Human Health Risk Assessments for Hazardous Waste Sites in Maine" (MEDEP, 2009b).

The dose-response values used to derive the soil guidelines were selected by MEDEP using the hierarchy of sources described in "Guidance for Human Health Risk Assessments for Hazardous Waste Sites in Maine" (MEDEP, 2009b). The dose-response values used by MEDEP to derive risk-based guidelines for the petroleum hydrocarbon fractions were those developed by MassDEP (MassDEP, 2003).

The risk-based soil guidelines for petroleum fractions and TAL parameters developed by MEDEP do not account for migration of vapors to indoor air or migration to groundwater. In addition, the guidelines used in this report to derive cleanup levels for DRO and GRO do not account for ceiling concentrations. Consequently, the risk-based cleanup levels for DRO and GRO are protective for direct contact exposures to soil, and not for migration to indoor air or leaching to groundwater. Cleanup levels for DRO and GRO that are protective for leaching to groundwater are provided in Section 3.

The risk-based guidelines for petroleum hydrocarbon fractions and TAL parameters that were derived in "Remediation Guidelines for Petroleum Contaminated Sites in Maine" (MEDEP, 2010) were calculated for a target cancer risk of $1x10^{-6}$ for each compound, and a target hazard index of 0.2 for each compound, which represent one-tenth and one-fifth of the MEDEP cumulative cancer and non-cancer risk limits, respectively. MEDEP established the risk-based guidelines at target risk levels that are a fraction of the MEDEP cumulative risk limits to ensure that cleanup of petroleum mixtures consisting of petroleum fractions and TAL parameters would be protective for the MEDEP cumulative risk limits of a cancer risk of $1x10^{-5}$ and a hazard index of 1. For TAL parameters that had a cancer and non-cancer based endpoint (e.g., benzene), the lower of the cancer and non-cancer risk-based guidelines were used by MEDEP as the soil guideline. The risk-based guidelines for petroleum fractions and TAL parameters that are relevant for derivation of DRO and GRO cleanup levels are presented in Table 1.

The cleanup levels for DRO and GRO derived in this document account for mixtures of petroleum fractions and TAL parameters. Therefore, the risk-based guidelines for petroleum fractions and TAL parameters shown in Table 1 were adjusted to reflect guidelines corresponding to a cancer risk of $1x10^{-5}$ and a hazard index of 1. This enabled the DRO and GRO cleanup levels for each petroleum source material to be protective for petroleum mixtures at the MEDEP cumulative risk limits. The adjusted guidelines for petroleum fractions and TAL parameters are shown in Table 1; the lower of the guidelines based on a cancer risk of $1x10^{-5}$ and a hazard index of 1 were identified and used to derive the cleanup levels for GRO and DRO, as described in Section 2.2.

2.2 RISK-BASED CLEANUP LEVELS FOR PETROLEUM HYDROCARBON MIXTURES

As identified in Section 1, in order to derive risk-based cleanup levels that can be used to evaluate GRO and DRO analytical data, the petroleum hydrocarbon composition of a petroleum product, in terms of aliphatic and aromatic hydrocarbon fractions and target analytes that are considered to be toxicologically significant, must be identified. Since DRO and GRO analytical procedures do not provide hydrocarbon fraction data, the composition of the petroleum source materials for which cleanup guidelines are being developed, in terms of hydrocarbon fractions and TAL parameters, was identified from the literature. This information was then used with the risk-based concentrations for the hydrocarbon fractions and TAL parameters (Section 2.1) to derive risk-based cleanup levels for each of the petroleum source materials.

2.2.1 Petroleum Source Material Composition

A literature review was performed to identify the petroleum hydrocarbon composition that is associated with each of the six petroleum products. Attachment A provides summaries of the hydrocarbon compositional information for each of the petroleum products evaluated in this report.

Hydrocarbon Fractions

Hydrocarbon compositional information was generally available for hydrocarbon size (number of carbon atoms) and hydrocarbon structure, but not always for both hydrocarbon size and structure. In addition, compositional information often included data for non-TAL analytes and hydrocarbon structures that are greater than C36, indicating that they are of insignificant toxicity. The compositional information provided in Attachment A was reviewed and assigned to

equivalent MassDEP hydrocarbon fractions, as appropriate. Tables 2 through 6 present the assumed composition for each of the petroleum products evaluated in this report.

Target Analyte List Parameters

TAL parameters of interest in petroleum source materials include BTEX, MTBE (gasoline only), and PAHs. Among PAHs, benzo(a)pyrene and dibenz(a,h)anthracene are associated with the highest order of toxicity among the seven potentially carcinogenic PAHs, and naphthalene is associated with the highest order of toxicity among the non-carcinogenic PAHs. The reference dose (RfD) values for all other non-carcinogenic PAHs are equal to or higher than (less toxic than) the RfD for the C11-C22 aromatic hydrocarbon fraction. Given that all TAL PAHs are included in the total C11-C22 aromatic hydrocarbon fraction, it is only necessary to account for the composition of naphthalene and the potentially carcinogenic PAHs separately as TAL parameters. To address the potentially carcinogenic PAHs in a streamlined manner, the sum composition of all potentially carcinogenic PAHs in a petroleum mixture are counted as benzo(a)pyrene and the risk-based concentration for benzo(a)pyrene is applied. Although this provides an overestimate of the toxicity of the carcinogenic PAHs, the PAHs overall represent a minor fraction of the total petroleum mixtures.

Tables 2 through 6 provide the assumed hydrocarbon composition and rationale for the composition for each of the petroleum products. The composition for an unknown petroleum source is based on the assumption that it is entirely composed of the hydrocarbon fraction that is associated with the highest order of toxicity. Therefore, the composition for an unknown petroleum hydrocarbon measured as GRO is based on the assumption that it is C9-C10 aromatics, and the composition for an unknown petroleum hydrocarbon measured as DRO is based on the assumption that it is C11-C22 aromatics. In cases where the cleanup level for unknown petroleum is applied, the source of petroleum is assumed to not be known. Therefore, the contribution of TAL parameters to the composition of the unknown petroleum product cannot be identified. Consequently, cleanup levels that include compositional assumptions for TAL parameters were not derived for the unknown petroleum product.

2.2.2 Calculation of Risk-Based Cleanup Levels

Risk-based cleanup levels are calculated for each land use scenario, for each of the six petroleum source materials evaluated. Risk-based cleanup levels are calculated using the risk-based concentrations identified in Section 2.1 with the compositional information presented in section

2.2.1, such that the concentrations of the petroleum fractions and TAL parameters associated with the cleanup level of the petroleum mixture do not exceed their individual risk-based concentrations, as shown in the following equation:

$$Cleanup\ Level = 1/[(fractional\ comp.\ of\ compound_a/RBC_a) + (fractional\ comp.\ of\ compound_b/RBC_b)\ldots n]$$

Where:

Cleanup Level	=	*Soil cleanup level for petroleum measured as DRO or GRO, for the product-specific or unknown petroleum source (mg/kg)*
fractional comp. of compound$_a$	=	*Fraction of the petroleum source represented by fraction$_a$ or TAL$_a$ from Tables 2 – 6 (dimensionless)*
RBC$_a$	=	*Risk-based soil guideline for fraction$_a$ or TAL$_a$ as shown in Table 1 (mg/kg)*

Two sets of risk-based cleanup levels have been calculated for gasoline, No. 2 fuel oil, No. 6 fuel oil, and used crankcase oil. One set excludes compositional assumptions for TAL parameters, and is intended to be used with site data sets that include both DRO/GRO analyses and TAL analyses. The second set includes compositional assumptions for TAL parameters, and is intended to be used with site data sets for which no TAL analyses are available.

The hydrocarbon compositions for gasoline, No. 2 fuel oil, No. 6 fuel oil, and used crank case oil include adjusted and unadjusted values for some petroleum fractions (e.g., C11-C22 aromatics for No. 2 fuel oil). The adjusted values reflect the percentage of TAL parameters subtracted from the total fraction (e.g., the percentage of naphthalene and carcinogenic PAHs subtracted from the total C11-C22 percentage). The adjusted values are used in the calculation of cleanup levels that factor in the contribution from the TAL parameters. The unadjusted values are used in the calculation of cleanup levels that do not factor in the contribution from TAL parameters.

The MEDEP RAGs guidelines incorporate a ceiling concentration of 10,000 milligrams per kilogram (mg/kg). Therefore an additional set of cleanup levels was derived to factor in a ceiling concentration of 10,000 mg/kg. These levels were calculated by establishing the risk-based concentrations for petroleum fractions and TAL parameters at the lesser of the risk-based concentration or the ceiling concentration of 10,000 mg/kg, and then proceeding with the

calculation of the petroleum mixture as described above. These cleanup levels are also presented in Tables 2 through 6.

The cleanup levels can be verified by calculating the hazard index and cancer risk that would be associated with exposure to the cleanup level concentration in soil if it was measured by DRO (or GRO). Table 2 provides an example for gasoline. As shown in Table 2, if the residential cleanup levels for gasoline of 5,271 mg/kg (for use with TAL data available) and 2,229 mg/kg (for use with TAL data unavailable) were measured by GRO in soil, and the compositional assumptions for gasoline shown in Table 2 were applied to the measured result, the hazard index and cancer risk would not exceed the MEDEP cumulative non-cancer risk limit of a hazard index of 1 or the MEDEP cumulative cancer risk limit of $1x10^{-5}$.

3.0 DERIVATION OF LEACHING-BASED CLEANUP LEVELS

The technical approach for deriving leaching-based cleanup levels is similar to the approach that has been used to derive risk-based cleanup levels. The approach involves first identifying leaching-based guidelines for individual petroleum hydrocarbon fractions and TAL parameters. The leaching-based guidelines are then applied with the petroleum compositional information provided in Section 2.2, to derive leaching-based cleanup levels for the six petroleum source materials evaluated in this report.

3.1 LEACHING-BASED GUIDELINES FOR PETROLEUM HYDROCARBON FRACTIONS AND TARGET ANALYTE LIST PARAMETERS

A leaching-based guideline is a chemical concentration in soil which ensures that migration (leaching) of the chemical from soil to groundwater, if such migration were to occur, will not result in a concentration in groundwater that poses a health risk of concern. In order to derive leaching-based cleanup levels for petroleum hydrocarbon mixtures, leaching-based guidelines must first be identified for each of the hydrocarbon fractions and TAL parameters that are contained in the petroleum mixtures.

MEDEP has derived leaching-based guidelines for individual petroleum hydrocarbon fractions as well as TAL parameters in "Remediation Guidelines for Petroleum Contaminated Sites in Maine" (MEDEP, 2009a). The leaching-based guidelines were derived using SESOIL and AT123D modeling which assumed that petroleum-contaminated soil contacts a groundwater table located 15 feet below ground surface, and that a well (the exposure point for petroleum-contaminated water) is located 50 feet downgradient of the soil contamination. The leaching-based guidelines for soil were derived such that, under these simulated leaching conditions, concentrations of petroleum fractions and TAL parameters in groundwater would not exceed the Maine drinking water guidelines (Maximum Exposure Guidelines [MEGs]) at the downgradient well. Consequently, the leaching-based guidelines are protective for groundwater that could be used as a source of potable water.

The technical approach used by MEDEP to derive leaching-based guidelines is provided in Appendix C (Technical Basis and Background for the Maine Petroleum Soil Guidelines) of "Remediation Guidelines for Petroleum Contaminated Sites in Maine" (MEDEP, 2009a). That approach is consistent with the approach used by MEDEP to derive the Maine RAGs as described

in "Technical Basis and Background for the Maine Remedial Action Guidelines" (MEDEP, 2010).

The leaching-based guidelines derived by MEDEP are provided in Table 7. As indicated in Table 7, MEDEP determined that several of the constituents associated with petroleum would not likely leach and, therefore, has determined that leaching-based guidelines do not apply to those constituents (indicated with an 'NA' in Table 7).

The leaching-based guidelines for petroleum hydrocarbon fractions and TAL parameters that were derived in "Remediation Guidelines for Petroleum Contaminated Sites in Maine" (MEDEP, 2010) were calculated to be protective for groundwater concentrations at the MEDEP MEGs. Since compliance with MEGs does not require consideration of cumulative risks for multiple chemicals that may be present, the derivation of leaching-based cleanup levels for DRO and GRO do not need to account for additive risks among petroleum fractions and TAL parameters.

3.2 LEACHING-BASED CLEANUP LEVELS FOR PETROLEUM HYDROCARBON MIXTURES

Leaching-based cleanup levels are calculated for each of the six petroleum source materials evaluated in this report as shown in Tables 8 through 12. Leaching-based cleanup levels are calculated using the leaching-based concentrations identified in Section 3.1 with the compositional information presented in section 2.2.1. Specifically, a leaching-based cleanup level is calculated for each of the petroleum fractions and TAL parameters by adjusting the leaching-based guidelines presented in Table 7 to account for percentage composition of the petroleum fraction or TAL in the mixture, as follows:

$$Cleanup\ Level_a = (LBC_a / fractional\ comp.\ of\ compound_a]$$

Where:

$Cleanup\ Level_a$	=	*Soil leaching-based cleanup level for fraction$_a$ or TAL$_a$ (mg/kg)*
$fractional\ comp.\ of\ compound_a$	=	*Fraction of the petroleum source represented by fraction$_a$ or TAL$_a$ from Tables 8 – 12 (dimensionless)*
LBC_a	=	*Leaching-based guideline for fraction$_a$ or TAL$_a$ as shown in Table 7(mg/kg)*

Once leaching-based cleanup levels are calculated for each of the fractions and TAL parameters for a given petroleum mixture, the lowest of the levels is then identified as the leaching-based cleanup level for the mixture. This level, being the lowest among all the substances within the mixture, is protective for leaching of any of the substances within the petroleum mixture, and therefore protective for the mixture.

Two sets of leaching-based cleanup levels have been calculated for each of the following source materials: gasoline, No. 2 fuel oil, No. 6 fuel oil, and used crankcase oil. One set excludes compositional assumptions for TAL parameters, and is intended to be used with site data sets that include both DRO/GRO analyses and TAL analyses. The second set includes compositional assumptions for TAL parameters, and is intended to be used with site data sets for which no TAL analyses are available.

The hydrocarbon compositions for gasoline, No. 2 fuel oil, No. 6 fuel oil, and used crank case oil include adjusted and unadjusted values for some petroleum fractions (e.g., C11-C22 aromatics for No. 2 fuel oil). The adjusted values reflect the percentage of TAL parameters subtracted from the total fraction (e.g., the percentage of naphthalene and carcinogenic PAHs subtracted from the total C11-C22 percentage). The adjusted values are used in the calculation of cleanup levels that factor in the contribution from the TAL parameters. The unadjusted values are used in the calculation of cleanup levels that do not factor in the contribution from TAL parameters.

None of the leaching-based cleanup levels presented in Tables 8 through 12 exceeds the MEDEP ceiling concentration of 10,000 mg/kg.

4.0 APPLICATION OF RISK-BASED LEVELS

The risk-based cleanup levels derived in Section 2, and the leaching-based cleanup levels derived in Section 3, can be used to evaluate petroleum hydrocarbon data reported as DRO, GRO, or total petroleum hydrocarbon (TPH) using one or more of the following approaches:

1) When the petroleum source material that is being measured by the GRO or DRO analysis is known, then the cleanup level for that petroleum product may be used. For example, if samples are collected from soil that has been impacted by a leaking No. 2 heating oil underground storage tank (UST), then a management decision could be made to use the cleanup levels for No. 2 heating oil. Since the cleanup levels are derived to be protective for the MEDEP cumulative risk limits, the exposure point concentration (EPC) of petroleum measured as DRO or GRO in soil can be compared directly to the cleanup level.

2) When the petroleum source material that is being measured by the GRO or DRO analysis is not known, is uncertain, or represents a mixture of various petroleum sources, then the cleanup levels for unknown petroleum could be used, or a chemist could perform a review of the chromatograms to make a determination of the probable petroleum source material(s), as discussed in Section 4.2, and the most appropriate (and conservative) cleanup level could be selected. Note that if the cleanup level for unknown petroleum products is used, then TAL data must also be obtained, because the cleanup level for unknown petroleum does not include compositional assumptions for TAL parameters. Since the cleanup levels are derived for a hazard index of 1 (the MEDEP non-cancer risk limit), the EPC of petroleum measured as DRO or GRO in soil can be compared directly to the cleanup level.

3) When both DRO and GRO data are used to report petroleum hydrocarbon concentrations in the same soil sample, it is recommended that a chemistry review be performed to identify the likely petroleum source material so that the appropriate cleanup levels can be selected. Once the appropriate cleanup levels are selected, the cleanup levels must be compared to the soil EPCs using a sum of ratios approach, as follows:

   $$(\text{GRO EPC}/\text{GRO cleanup level}) + (\text{DRO EPC}/\text{DRO cleanup level}) \leq 1.$$

   This approach ensures that the total risk associated with potential exposures to the petroleum measured as DRO and GRO would not exceed the cumulative risk limits.

4) In all cases, the cleanup levels that are selected must be matched with the type of analytical data that are available for the release area. Specifically, if no TAL data are available (i.e., only DRO and/or GRO data are available), then the cleanup levels that include a compositional allocation for TAL parameters should be used. Conversely, if TAL data are available, then the petroleum cleanup levels that do not include a compositional allocation for TAL parameters may be used. In these cases, data for TAL parameters should be evaluated separately with cleanup levels for the TAL parameters.

It is recommended that in all cases, a chemistry review of chromatograms be conducted, as described in Section 4.1. In all cases, a determination of whether to apply the cleanup levels that include TAL parameters would be made in consideration of whether separate analyses and data are available for TAL parameters.

4.1 ANALYTICAL METHODS

It is assumed that the data that were collected to characterize petroleum contamination in soil were developed using Maine Health and Environmental Testing Laboratory (HETL) methods for GRO and DRO (HETL, 1995a; HETL, 1995b). Additional data from other USEPA analytical methods such as USEPA SW-846 Test Methods for Evaluating Solid Waste (USEPA, 1996) may also be used to evaluate the chemical composition of hydrocarbon contamination at a site.

The MEDEP requires that laboratories providing analyses for GRO and DRO must be certified under the Maine Laboratory Certification Program administered by the Maine Health and Human Services Bureau of Health. Listings of certified laboratories are available on the web at http://www.maine.gov/dep/rwm/ust/lustqaplan.htm or by contacting the Laboratory Certification Officer.

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Gasoline Range Organics

The GRO method utilizes a gas chromatograph (GC) equipped with a flame ionization detector (FID). For soil testing, the samples are preserved in methanol at the time of sample collection. An aliquot of the methanol extract is introduced to the GC using a purge and trap device followed by GC/FID analysis. This procedure is used to determine the total concentration of fuel related organic compounds in the gasoline range that are present in the samples. The GRO result is defined as the total hydrocarbon response from MTBE [C5] to naphthalene (C10), and the result includes all aromatic and aliphatic hydrocarbons that are detectable with the GC/FID procedure.

Volatile Organic Compounds

Testing of soil samples using USEPA Method 8260 or USEPA Method 8021 can provide additional data to evaluate hydrocarbon composition by testing for specific fuel related chemicals that may be present in the GRO fraction (USEPA, 1996). Volatile organic compound (VOC) sample field preservation procedures specified in USEPA Method 5035 must be used when collecting soil samples analyzed using these methods. Data from samples collected without field preservation are not usable in the evaluation of fuel composition. The primary fuel related VOC target analytes that are used in the characterization of GRO fuel contamination are the aromatic BTEX compounds.

USEPA Method 8260 is a GC procedure using a mass spectrometer detector (GC/MS). Both halogenated VOCs and BTEX compounds can be reported by this method. The use of the MS detector can reduce fuel related matrix interference that can be present in samples and provide accurate identification and quantitation of BTEX compounds.

USEPA Method 8021 is a GC procedure using a dual electrolytic conductivity detector/photo ionization detector (GC/ELCD/PID). Both halogenated VOCs and BTEX compounds can be reported by this method. The ELCD detector responds only to halogen containing compounds. The non-halogenated BTEX compounds are detected with the PID. It is possible to reduce the impact of matrix interference using the two different detectors, but there is still the possibility that halocarbon or fuel related matrix interference in samples will impact the quality of BTEX results.

Diesel Range Organics

The DRO method utilizes a GC/FID. For soil testing, the samples are collected in soil jars and chilled at the time of collection. Soils samples are extracted with solvent and the extract is directly injected into the GC device followed by GC/FID analysis. This procedure is used to determine the total concentration of fuel related organic compounds in the diesel range that is defined by the method. The DRO result is defined as the total hydrocarbon response from n-decane (C10) to n-octacosane (C28), and the result includes all aromatic and aliphatic hydrocarbons that detectable with the GC/FID procedure. The laboratories are required to extend the GC run beyond C28 out to the time when C36 hydrocarbons are detected. If the presence of hydrocarbons greater than the C28 range is suspected, a qualitative description of these hydrocarbons should be included in the lab report. This may be a statement in the package

narrative or a footnote on the sample report. The presence of hydrocarbons greater than C28 may indicate that the petroleum contamination contains/represents heavy motor oil, heavy fuel oil, or lubricating oil.

Semi-volatile Organic Compounds

Testing of soil samples using USEPA Method 8270, Method 8100, or Method 8310 can provide additional data to evaluate hydrocarbon composition by testing for specific fuel related chemicals that may be present in the DRO fraction (USEPA, 1996). The primary fuel related semi-volatile organic compound (SVOC) target analytes that are used in the characterization of DRO fuel contamination are the PAH. The USEPA has identified a list of 16 PAH compounds that are listed as target compounds under Methods 8270, 8100, and 8310. A subset of these PAH compounds have been identified as probable human carcinogens by the USEPA Integrated Risk Information System. The PAH compounds listed below represent the appropriate target compounds list for further characterization of DRO:

PAH ANALYTE	**CPAH**
Naphthalene	
Acenaphthylene	
Acenaphthene	
Fluorene	
Phenanthrene	
Anthracene	
Fluoranthene	
Pyrene	
Benzo(a)anthracene	X
Chrysene	X
Benzo(b)fluoranthene	X
Benzo(k)fluoranthene	X
Benzo(a)pyrene	X
Indeno(1,2,3-cd)pyrene	X
Dibenz(a,h)anthracene	X
Benzo(g,h,i)perylene	

CPAH – carcinogenic poly aromatic hydrocarbon

USEPA Method 8270 is a GC/MS procedure. Both halogenated SVOCs and non-halogenated compounds can be reported by this method. The use of the MS detector can reduce fuel related matrix interference that can be present in samples and provide accurate identification and

quantitation of PAH compounds. Method 8270 can be modified to detect PAH using Selective Ion Monitoring (SIM) to obtain low detection limits for PAH compounds.

USEPA Method 8100 is a GC/FID procedure. This method is subject to matrix interference from non-PAH fuel hydrocarbons that may decrease the quality of PAH results. An extract cleanup step using Method 3630 should be performed to remove aliphatic hydrocarbons matrix interference and improve the quality of PAH data generated with this method.

USEPA Method 8310 is a high performance liquid chromatography (HPLC) procedure using a fluorescence/ultraviolet (UV) detector. This method is subject to matrix interference from non-PAH fuel hydrocarbons that may decrease the quality of PAH results. However, many interfering compounds present in fuels (non-PAH) have a low response on the UV detector and good resolution of PAH compounds may be possible without additional cleanup. An extract cleanup step using Method 3630 can be performed to remove aliphatic hydrocarbons matrix interference and improve the quality of PAH data generated with this method.

4.2 FINGER PRINT EVALUATIONS

A fingerprint evaluation can be completed to identify the type of petroleum product that is present in soils. During the fingerprint analysis, standards of fuel types including gasoline, kerosene, diesel/Fuel Oil #2, and motor oils are analyzed during instrument calibration. Chromatographic fingerprints from sample analyses are compared to chromatographic runs of fuel standards to attempt to identify the type of fuel that caused the contamination. Fingerprint analysis may be completed using USEPA Method 8015 or a modified DRO analysis.

Identification of Petroleum Product

For most sample analyses a general identification of the petroleum product type that is present in samples can be made by reviewing the sample chromatograms and evaluating the retention times of the hydrocarbon signatures. Retention times are reported in minutes and represent the amount of time that has passed since the sample was injected into the GC to when the analyte passes the detector. Light hydrocarbons have shorter retention times and elute early in the run. Heavy hydrocarbons have longer retention times and elute later in the run. In the GRO and DRO methods, calibration standards are analyzed that consist of chemical components representing a range of hydrocarbon weights that cover the hydrocarbon weight range evaluated in the methods.

By comparing the retention times of fuel hydrocarbons detected in samples to the retention times of standard components, it may be possible to identify the fuel product as gasoline, kerosene, fuel oil, motor oil, or mineral spirits. When using data obtained from the Maine GRO and DRO analyses to identify product types, there is a need for professional judgment and interpretation when evaluating actual field samples. Information on the historical activities at sites should be used in combination with an evaluation of chromatograms. The effects of weather discussed in Section 4.3 should also be considered.

An illustration of a DRO component standard is presented in Figure 1. This figure includes a subset of n-alkanes from C9 through C36. As discussed in Section 4.1, the DRO result is defined as the total hydrocarbon response from n-decane (C10) to n-octacosane (C28). The laboratories are required to extend the GC run beyond C28 out to the time when C36 hydrocarbons elute, so data on products with heavier hydrocarbons are also captured in the DRO runs. Illustrations of common petroleum products are presented in the following figures:

Figure 2. Gasoline
Figure 3. Kerosene
Figure 4. Mineral Spirits (Stoddard Solvent)
Figure 5. Fuel Oil #2 (Diesel)
Figure 6. Fuel Oil #4
Figure 7. Fuel Oil #6
Figure 8. Motor Oil

As indicated, figures are included for some petroleum products (kerosene, No. 4 oil, fresh motor oil) for which cleanup levels were not requested by MEDEP; these figures are presented for informational purposes.

Gasoline

Figure 2 is a chromatogram from a DRO analysis run of a gasoline standard. In the DRO chromatogram in Figure 2, only the heavier components of the gasoline analysis are detected. Lighter fractions are lost in a solvent front that passes prior to the C9 hydrocarbon component. During the DRO sample preparation, light compounds found in gasoline are also lost and not detected in the analysis. The light components are only measured in the GRO analysis. However, it is possible to detect the heavy end of gasoline in a DRO analysis, and DRO may be reported at sites that contain only gasoline. In the DRO run all gasoline components have

retention times that are shorter that the C16. The C16 cutoff can be used to establish that a product consists only of gasoline.

Kerosene

Figure 3 is a chromatogram from a DRO analysis of a kerosene standard. The majority of the kerosene hydrocarbons fall within the DRO range. In the DRO run all kerosene components have retention times that are shorter that the C20. The C20 cutoff can be used to distinguish kerosene from other fuel oils. However, it may not be possible to determine if the product is a combination of gasoline and kerosene. Aviation jet fuels will have a similar chromatographic pattern as kerosene, and it may not be possible to distinguish these products from kerosene.

Mineral Spirits

Figure 4 is a chromatogram from a DRO analysis of mineral spirits. Mineral spirits (also called Stoddard solvent) consist of highly refined hydrocarbons in the C5 to C11 range and the heaviest components detected in DRO analysis are generally lighter that C14. Lighter fractions are lost in a solvent front that passes prior to the C9 hydrocarbon component. During the DRO sample preparation, light compounds are lost and not detected in the DRO analysis. The light components are only measured in the GRO analysis. Commercial mineral spirit products vary in composition between sources and the DRO chromatogram in Figure 3 is provided only as a general reference for identification of mineral spirits. It may not be possible to distinguish between mineral spirits and gasoline using the DRO run.

Fuel Oils

Fuel oil consists of a variety of products. The most common products are Fuel Oil #2, Fuel Oil #4, and Fuel Oil #6. Diesel fuel is generally considered to be the same composition as Fuel Oil #2. Figure 5, Figure 6, and Figure 7 are DRO chromatograms of Fuel Oil #2, Fuel Oil #4, and Fuel Oil #6, respectively. For Fuel Oil #2 the weight range of hydrocarbons does not extend beyond the C28 retention time. The weight range of Fuel Oil #4 and Fuel Oil # 6 extends beyond the C28 range and continues out into the C36 retention time range.

Motor Oil

Figure 8 is a chromatogram from a DRO analysis of motor oil (lube oil). Motor oils have a distinctive narrow and dominant rise at the end of the DRO range (C26 to C28) that extends out

beyond the C36 retention time. The majority of the hydrocarbon response is beyond the retention time of the C18 component.

4.3 FUEL WEATHERING

Hydrocarbon products in the environment undergo weathering that changes the overall chemical composition from that of a fresh standard. Chromatograms presented in Figures 2 through 8 are from product samples that have not undergone environmental weathering.

In an unweathered oil sample the dominant n-alkane peaks stand prominently above the hydrocarbon hump and a bell shape curve extends from the light end of the chromatogram response to the extent of the detect hydrocarbon range. In more weathered samples, the n-alkane peaks decrease in size and fewer prominent peaks are observed along the crest of the hydrocarbon hump. In highly weathered samples, the majority of the hydrocarbons at the light end of the retention time range may be gone. The potential for weathering must be considered when comparing sample chromatograms to these figures and making interpretations on the type of product that is present.

When applying a risk-based cleanup level, it is important to recognize that weathering, while reducing the concentration of the volatile and more toxic light-end hydrocarbons, will in turn result in a greater percentage of the petroleum hydrocarbon mixture being present as heavier-end hydrocarbons and aromatics. Consequently, it is possible that the risk-based cleanup levels derived in this report could underestimate the percentage composition of aromatics, particularly C11-C22 aromatics, in highly weathered samples. Depending on the original petroleum source material, this could result in an underestimation or overestimation of the cleanup levels. In such cases, the cleanup levels for the C11-C22 aromatic fraction should be applied, ideally with separate TAL data and TAL cleanup levels, to evaluate the petroleum hydrocarbon contamination.

4.4 LABORATORY DATA DELIVERABLE VARIABILITY

Requirements for the reporting of laboratory results for GRO and DRO were not standardized and had to be defined with the laboratory when contracting analytical services. This was especially true if the nature of the hydrocarbon contamination was not known and product identification was necessary. The GRO and DRO methods describe analytical procedures and quality

assurance/quality control (QA/QC) requirements of the method, but they do not specify formats for laboratory data deliverables. Data deliverables may include summary reports of sample results, QC summary information, and supporting raw data such as instrument calibration summaries, chromatograms and instrument printouts, sample preparation, or laboratory notebook records. To ensure that adequate data are included in the laboratory deliverable to support and document product identification, the following items are needed in the laboratory report to properly use this guidance:

- a data package narrative including statements from the laboratory that summarize any QC issues from the analyses;
- lab chemist interpretations on the nature of petroleum that is detected in the samples; and
- raw data including quantitation reports and chromatograms for all standards, field samples, and QC blanks.

When data validation was required for a project, the reporting of additional sample custody and handling documents and requirements for the reporting of QC information and supporting data would have been established in consultation with the laboratory.

Data Quality Review

It is recommended that a data review process is completed on sample data to verify the nature of contamination reported in samples, unless there is documentation in the project file showing that this has already been completed. The package narrative should be reviewed to see if the laboratory is providing interpretations on the nature of contamination in the sample. In the GRO and DRO analyses, interferences from non-petroleum chemicals may create situations where GRO or DRO is reported when it is not present (false positive). This may include halocarbons, phthalates, or other chemicals that respond on the FID. Interference from non-petroleum chemicals will usually appear as isolated peaks in the chromatogram and the signature of fuels that are illustrated in Figures 2 through 8 may not be present in the chromatogram. Laboratories will usually include a statement in the narrative if this is observed in samples.

5.0 SUMMARY

Table 13 presents a summary of risk-based cleanup levels and leaching-based cleanup levels for soils that were derived for gasoline, No. 2 heating oil/diesel, No. 6 heating oil, used crankcase oil, Stoddard solvent, and unknown petroleum product. The risk-based cleanup levels were derived to be protective for direct contact exposures to soil associated with a hazard index of 1 and a cancer risk of 1 in 100,000, for four different receptor populations that may occur under residential and commercial/industrial land uses: residents, full-time outdoor commercial/industrial workers, construction workers, and park visitors. These cleanup levels do not address migration of vapors to indoor air. The leaching-based cleanup levels were derived to be protective for migration of petroleum mixtures to groundwater that could be used as drinking water. The cleanup levels were derived using risk-based soil guidelines published by MEDEP, MEGs published by MEDEP, and petroleum source product compositional data from the literature. Included in Table 13 is a second set of cleanup levels that are derived in consideration of the ceiling concentration of 10,000 mg/kg that has been used in the derivation of the MEDEP RAGs.

The cleanup levels presented in Table 13 may be used to evaluate petroleum hydrocarbon data that has been reported as DRO and/or GRO, and should be applied using the following guidelines:

- When the petroleum source material that is being measured by the DRO or GRO analysis is known, then the cleanup level for that petroleum product may be used.
- When the petroleum source material that is being measured by the DRO or GRO analysis is not known, is uncertain, or represents a mixture of various petroleum sources, then a chemist should perform a review of the chromatograms to make a determination of the probable petroleum source material(s), and the most appropriate (and conservative) cleanup level can then be selected. If it is not possible for a chemist to determine the probable petroleum source material(s), then the cleanup level for unknown petroleum could be used. For weathered products and unknown petroleum product, the GRO/DRO cleanup levels in this document may under or over estimate risk, and should be used with caution. Ideally, for weathered and unknown product, the GRO/DRO cleanup levels should only be applied when you also have analytical results for TAL compounds.
- When both DRO and GRO data are used to report petroleum hydrocarbon concentrations in the same soil sample, it is recommended that a chemistry review be performed to identify the likely petroleum source material so that the appropriate cleanup levels can be selected. Once the appropriate cleanup levels are selected, the cleanup levels should be applied using a sum of ratios approach to ensure that the summation of DRO and GRO

concentrations would not be associated with cumulative risks greater than the MEDEP cumulative risk limits.

- In all cases, the cleanup levels that are selected must be matched with the type of analytical data that are available for the release area. Specifically, if no TAL data are available (i.e., only DRO and/or GRO data are available), then the cleanup levels that include a compositional allocation for TAL parameters should be used. Conversely, if TAL data are available, then the petroleum cleanup levels that do not include a compositional allocation for TAL parameters may be used. In these cases, data for TAL parameters should be evaluated separately with cleanup levels for the TAL parameters.

It is recommended that petroleum hydrocarbon data reported using DRO and/or GRO analyses include a finger-print analysis. Review of the finger print analysis by a chemist can help identify the petroleum sources that are represented by the GRO and/or DRO data. This, in turn, can facilitate use of the most appropriate risk-based cleanup level.

6.0 REFERENCES

Indiana Department of Environmental Management (IDEM), February 15, 2001. Risk Integrated System of Closure Technical Guide.

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Massachusetts Department of Environmental Protection (MassDEP), October 31, 2002. *"Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MADEP EPH/VPH Approach"*. Final Policy #WSC-020411.

MassDEP, November, 2003. *"Final Updated Petroleum Hydrocarbon Fraction Toxicity Values for the VPH/EPH/APH Methodology"*.

TABLES

Table 1
Risk Based Criteria for EPH/VPH Fractions and Target Analytes
Derivation of Cleanup Levels for GRO and DRO

Resident

Child	Parameter	Soil Guideline (HQ=0.2, ELCR=1E-06)				Soil Guideline (HQ=1, ELCR=1E-05)			
	Benzene	**17**	**nc**	26	c	**85**	**nc**	257	c
	Ethylbenzene	3,400	nc	**128**	**c**	16,998	nc	**1,275**	**c**
	Toluene	**2,725**	**nc**			**13,624**	**nc**		
	Xylenes	**6,636**	**nc**			**33,179**	**nc**		
	Benzo(a)pyrene			**0.026**	**c**			**0.26**	**c**
	Naphthalene	387	nc	**197**	**c**	**1,935**	**nc**	1,966	c
	C9-C18 Aliphatics	**2,629**	**nc**			**13,143**	**nc**		
	C19-C36 Aliphatics	**53,229**	**nc**			**266,146**	**nc**		
	C11-C22 Aromatics	**730**	**nc**			**3,649**	**nc**		
	C5-C8 Aliphatics	**1,362**	**nc**			**6,808**	**nc**		
	C9-C12 Aliphatics	**2,639**	**nc**			**13,195**	**nc**		
	C9-C10 Aromatics	**742**	**nc**			**3,710**	**nc**		

Outdoor Commercial Worker

Adult	Parameter	Soil Guideline (HQ=0.2, ELCR=1E-06)				Soil Guideline (HQ=1, ELCR=1E-05)			
	Benzene	170	nc	**86**	**c**	**848**	**nc**	857	c
	Ethylbenzene	33,242	nc	**417**	**c**	166,208	nc	**4,171**	**c**
	Toluene	**27,195**	**nc**			**135,975**	**nc**		
	Xylenes	**51,725**	**nc**			**258,627**	**nc**		
	Benzo(a)pyrene			**0.35**	**c**			**3.5**	**c**
	Naphthalene	1,043	nc	**200**	**c**	5,214	nc	**2,000**	**c**
	C9-C18 Aliphatics	**18,418**	**nc**			**92,088**	**nc**		
	C19-C36 Aliphatics	**410,442**	**nc**			**2,052,209**	**nc**		
	C11-C22 Aromatics	**4,471**	**nc**			**22,356**	**nc**		
	C5-C8 Aliphatics	**13,507**	**nc**			**67,536**	**nc**		
	C9-C12 Aliphatics	**19,045**	**nc**			**95,226**	**nc**		
	C9-C10 Aromatics	**5,065**	**nc**			**25,326**	**nc**		

Construction Worker

Adult	Parameter	Soil Guideline (HQ=0.2, ELCR=1E-06)				Soil Guideline (HQ=1, ELCR=1E-05)			
	Benzene	**30**	**nc**	693	c	**151**	**nc**	6,925	c
	Ethylbenzene	15,667	nc	**2,682**	**c**	78,333	nc	**26,816**	**c**
	Toluene	**39,447**	**nc**			**197,233**	**nc**		
	Xylenes	**7,036**	**nc**			**35,181**	**nc**		
	Benzo(a)pyrene			**4.3**	**c**			**43**	**c**
	Naphthalene	**32**	**nc**	217	c	**158**	**nc**	2,169	c
	C9-C18 Aliphatics	**7,286**	**nc**			**36,432**	**nc**		
	C19-C36 Aliphatics	**285,874**	**nc**			**1,429,371**	**nc**		
	C11-C22 Aromatics	**4,706**	**nc**			**23,529**	**nc**		
	C5-C8 Aliphatics	**12,013**	**nc**			**60,064**	**nc**		
	C9-C12 Aliphatics	**9,769**	**nc**			**48,846**	**nc**		
	C9-C10 Aromatics	**5,498**	**nc**			**27,489**	**nc**		

Park Visitor

Adolescent	Parameter	Soil Guideline (HQ=0.2, ELCR=1E-06)				Soil Guideline (HQ=1, ELCR=1E-05)			
	Benzene	**28**	**nc**	43	c	**142**	**nc**	429	c
	Ethylbenzene	5,666	nc	**213**	**c**	28,330	nc	**2,125**	**c**
	Toluene	**4,541**	**nc**			**22,707**	**nc**		
	Xylenes	**11,060**	**nc**			**55,299**	**nc**		
	Benzo(a)pyrene			**0.044**	**c**			**0.44**	**c**
	Naphthalene	645	nc	**328**	**c**	**3,225**	**nc**	3,276	c
	C9-C18 Aliphatics	**4,381**	**nc**			**21,905**	**nc**		
	C19-C36 Aliphatics	**88,715**	**nc**			**443,576**	**nc**		
	C11-C22 Aromatics	**1,216**	**nc**			**6,081**	**nc**		
	C5-C8 Aliphatics	**2,269**	**nc**			**11,347**	**nc**		
	C9-C12 Aliphatics	**4,398**	**nc**			**21,992**	**nc**		
	C9-C10 Aromatics	**1,237**	**nc**			**6,183**	**nc**		

Maine Department of Environmental Protection (MEDEP), 2009. "Remediation Guidelines for Petroleum Contaminated Sites in Maine." November 20.

HQ = Hazard Quotient
ELCR = Excess Lifetime Cancer Risk

nc = noncarcinogenic
c = carcinogenic
Bolded value is selected as the risk based value used in this document.

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Checked by / Date: JHP 03/18/10

Table 2
Gasoline - Derivation of Risk Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
Aliphatic C5-C8	45%	Based on IDEM, 2006; supported by Air Force, 1989, ATSDR,1995, and data in Attachment A.
Aliphatic C9-C18	12%	Based on IDEM, 2006
Aromatic C9-C10 (unadjusted)	43%	Based on IDEM, 2006; supported by Air Force 1989, ATSDR, 1995, and data in Attachment A.
Benzene	2%	Based on data in Attachment A.
Ethylbenzene	8%	Based on data in Attachment A.
Toluene	2%	Based on data in Attachment A.
Xylenes	9%	Based on data in Attachment A.
Naphthalenes	6%	Based on data in Attachment A.
Aromatic C9-C10 (adjusted)	16%	Unadjusted value with percentage ethylbenzene, toluene, xylenes, and naphthalenes subtracted.

			Using Ceiling of 10,000	
Receptor	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)
Resident	5,232	2,216	5,155	2,170
Park Visitor	8,720	3,694	7,902	3,436
Construction Worker	37,838	1,870	10,000	1,654
Outdoor Commercial Worker	40,088	11,423	10,000	6,379

$$\text{Cleanup Level} = \frac{\text{Target HI}}{\Sigma\ \text{Percent Weight / Risk-Based Concentration}}$$

Verification of Cleanup Value - Resident

		Cleanup value with TAL data available: 5,232		Cleanup value with TAL data unavailable: 2,216			
	Risk-Based Concentration	Concentration of parameter [a]	HQ [b]	Concentration of parameter [a]	Fraction [b]	HQ [b]	ELCR [c]
Aliphatic C5-C8	6,808	2,354	0.3	997	0.1	0.1	
Aliphatic C9-C18	13,143	628	0.05	266	0.02	0.02	
Aromatic C9-C10 (unadjusted)	3,710	2,250	0.6				
Benzene	85			44	0.5	0.5	(2E-06)
Ethylbenzene	1,275			177	0.1	(0.01)	1E-06
Toluene	13,624			44	0.003	0.003	
Xylenes	33,179			199	0.006	0.006	
Naphthalenes	1,935			133	0.07	0.07	(7E-07)
Aromatic C9-C10 (adjusted)	3,710			355	0.1	0.1	
		Hazard Index	1.0	Hazard Index	1.0	0.9	4E-06

[a] - (Cleanup value) X (percent weight)
[b] - (Concentration of parameter) / (risk-based concentration for parameter) [Each risk based concentration is based on a hazard index of 1.0)
[c] - (Concentration of parameter) X (1E-05) / (risk-based concentration for parameter) [Each risk based concentration is based on an ELCR of 1E-05]
( ) - ELCR calculated using the risk-based concentration derived for a cancer endpoint (presented in Table 1).
HQ calculated using the risk-based concentration derived for a non-cancer endpoint (presented in Table 1).
HQ = Hazard quotient
ELCR = Excess Lifetime Cancer Risk
TAL = Target Analyte List
mg/kg = milligrams per kilogram

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Table 3
Number 2 Fuel Oil - Derivation of Risk Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
Aliphatic C9-C18	78%	Based on IDEM, 2006 and supported by ATSDR 1995, and data in Attachment A (average total aromatics is 23%; the remainder is aliphatics).
Aromatic C11-C22 (unadjusted)	22%	Based on IDEM, 2006 and supported by ATSDR, 1995 and data in Attachment A (average total aromatics is 23%; the remainder is aliphatics).
Carcinogenic PAHs	0.36%	Based on data in Attachment A
Naphthalenes	6%	Based on data in Attachment A
Aromatic C11-C22 (adjusted)	16%	Unadjusted value with percentage cPAHs and naphthalenes subtracted.

			Using Ceiling of 10,000	
Receptor	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)
Resident	8,358	72	7,231	72
Park Visitor	13,930	120	8,758	120
Construction Worker	32,510	2,031	10,000	1,792
Outdoor Commercial Worker	54,613	935	10,000	872

$$\text{Cleanup Level} = \frac{\text{Target HI}}{\Sigma \text{ Percent Weight / Risk-Based Concentration}}$$

TAL = Target Analyte List
mg/kg = milligrams per kilogram

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Checked by/Date: JHP 03/18/10

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological profile for fuel oils. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
IDEM, 2006. RISC Technical Guide - Chapter 8. June 15.

Table 4
Number 6 Oil - Derivation of Risk Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
C11-C22 Aromatics (unadjusted)	70%	MassDEP, 2002
C9-C18 Aliphatics	30%	MassDEP, 2002
Carcinogenic PAHs	0.33%	Based on data in Attachment A
Naphthalenes	2.6%	Based on data in Attachment A
Aromatic C11-C22 (adjusted)	67%	Unadjusted value with percentage cPAHs and naphthalenes subtracted.

			Using Ceiling of 10,000	
Receptor	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)
Resident	4,658	78	4,507	78
Park Visitor	7,763	130	6,891	130
Construction Worker	26,326	3,588	10,000	2,950
Outdoor Commercial Worker	28,928	1,015	10,000	954

$$\text{Cleanup Level} = \frac{\text{Target HI}}{\Sigma \text{ Percent Weight / Risk-Based Concentration}}$$

TAL = Target Analyte List
mg/kg = milligrams per kilogram

Prepared by/Date: KJC 03/17/10
Checked by/Date: JHP 03/18/10

Massachusetts Department of Environmental Protection (MassDEP), 2002. "Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MADEP EPH/VPH Approach". Final Policy #WSC-020411. October 31.

Table 5
Used Crankcase Oil - Derivation of Risk Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
Aliphatic C9-C18	72%	Based on aliphatics from ATSDR, 1997; supported by sum of alkanes (80%) from Attachment A
Aromatic C11-C22 (unadjusted)	28%	Based on sum of aromatics (sum of maximum) from ATSDR, 1997; supported by total aromatics value (22%) from Attachment A
Carcinogenic PAHs	0.042%	Based on data in Attachment A
Naphthalenes	3.2%	Based on data in Attachment A
Aromatic C11-C22 (adjusted)	25%	Unadjusted value with percentage cPAHs and naphthalenes subtracted.

			Using Ceiling of 10,000	
Receptor	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)
Resident	7,603	574	6,723	569
Park Visitor	12,672	957	8,471	923
Construction Worker	31,583	4,117	10,000	3,233
Outdoor Commercial Worker	49,157	6,479	10,000	4,307

$$\text{Cleanup Level} = \frac{\text{Target HI}}{\Sigma\ \text{Percent Weight / Risk-Based Concentration}}$$

TAL = Target Analyte List
mg/kg = milligrams per kilogram

Prepared by/Date: KJC 03/17/10
Checked by/Date: JHP 03/18/10

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. Toxicological profile for used mineral-based crankcase oil. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Table 6
Stoddard Solvent - Derivation of Risk Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
Aliphatic C5-C8	20%	Based on Air Force, 1989. Assumes 80% alkanes; 20% of which are in the C5-C8 range
Aliphatic C9-C18	60%	Based on Air Force, 1989. Assumes 80% alkanes; 20% of which are in the C5-C8 range
Aromatic C11-C22	20%	Based on Air Force, 1989.

			Using Ceiling of 10,000	
Receptor	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)	DRO/GRO Cleanup Level with TAL Data Available (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable (mg/kg)
Resident	7,702	--	6,935	--
Park Visitor	12,836	--	8,858	--
Construction Worker	35,337	--	10,000	--
Outdoor Commercial Worker	54,280	--	10,000	--

$$\text{Cleanup Level} = \frac{\text{Target HI}}{\Sigma \text{ Percent Weight / Risk-Based Concentration}}$$

-- = TAL data not available.
TAL = Target Analyte List
mg/kg = milligrams per kilogram

Prepared by/Date: KJC 03/17/10
Checked by/Date: JHP 03/18/10

Air Force. 1989. Gasoline. In: The installation restoration program toxicology guide. Volume 4. Contract no. DE-AC05-840R21400. Wright-Patterson Air Force Base, OH. Document no. 65-I-65-46.

Table 7
Tier 1 Soil Remediation Guidelines
Based on Petroleum Leaching to Groundwater

Derivation of Cleanup Levels for GRO and DRO

Parameter	Concentration (mg/kg)
C9-C18 Aliphatics	--
C19-C36 Aliphatics	--
C11-C22 Aromatics	460
C5-C8 Aliphatics	1600
C9-C12 Aliphatics	--
C9-C10 Aromatics	75
Benzene	0.51
Ethylbenzene	0.81
Toluene	8.1
Xylenes	26
Naphthalene	1.7
Benzo(a)pyrene	--

Guidelines present the lower of soil concentrations derived for sand and gravel or sandy till soils using SESOIL leaching and AT123D dispersion/advection models, and Maine meteorological and geology data. The basis for the guidelines is presented in Appendix D of MEDEP, 2009.

-- means not applicable and indicates Department modeling predicted groundwater exceedance of MEG unlikely in 1,000 years regardless of soil concentration.

mg/kg = milligrams per kilogram

Maine Department of Environmental Protection (MEDEP), 2009. "Remediation Guidelines for Petroleum Contaminated Sites in Maine." November 20.

Prepared by / Date: KJC 03/17/10
Checked by / Date: JHP 03/18/10

Table 8
Gasoline - Derivation of Leaching Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
Aliphatic C5-C8	45%	Based on IDEM, 2006; supported by Air Force, 1989, ATSDR,1995, and data in Attachment A.
Aliphatic C9-C18	12%	Based on IDEM, 2006
Aromatic C9-C10 (unadjusted)	43%	Based on IDEM, 2006; supported by Air Force 1989, ATSDR, 1995, and data in Attachment A.
Benzene	2%	Based on data in Attachment A.
Ethylbenzene	8%	Based on data in Attachment A.
Toluene	2%	Based on data in Attachment A.
Xylenes	9%	Based on data in Attachment A.
Naphthalenes	6%	Based on data in Attachment A.
Aromatic C9-C10 (adjusted)	16%	Unadjusted value with percentage ethylbenzene, toluene, xylenes, and naphthalenes subtracted.

Cleanup Value by Percent Weight of Each Constituent

	Leaching Concentration (mg/Kg)	Leaching Concentration by Percent Weight [a] (mg/Kg)
Aliphatic C5-C8	1,600	3,556
Aliphatic C9-C18	--	--
Aromatic C9-C10 (unadjusted)	75	174
Benzene	0.51	26
Ethylbenzene	0.81	10.1
Toluene	8.1	405
Xylenes	26	289
Naphthalenes	1.7	28
Aromatic C9-C10 (adjusted)	75	469

$$\text{Cleanup Level} = \text{Min}\left(\frac{\text{Leaching Concentration}}{\text{Percent Weight}}\right)$$

Cleanup Values for DRO/GRO

	DRO/GRO Cleanup Level with TAL Data Available [b] (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable [c] (mg/kg)
Leaching to Groundwater	469	10.1

[a] (Leaching Concentration) / (Percent Weight)
[b] Lowest leaching concentration by weight of any EPH/VPH fraction; adjusted values are used when TAL data are available.
[c] Lowest leaching concentration by weight of any EPH/VPH fraction and TAL parameter.

TAL = Target Analyte List
mg/kg = milligrams per kilogram

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological profile for automotive gasoline. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
Air Force. 1989. Gasoline. In: The installation restoration program toxicology guide. Volume 4. Contract no. DE-AC05-840R21400. Wright-Patterson Air Force Base, OH. Document no. 65-I-65-46.
IDEM, 2006. RISC Technical Guide - Chapter 8. June 15.

Prepared by / Date: KJC 03/17/10
Checked by / Date: JHP 03/18/10

Table 9
Number 2 Fuel Oil - Derivation of Leaching Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
Aliphatic C9-C18	78%	Based on IDEM, 2006 and supported by ATSDR 1995, and data in Attachment A (average total aromatics is 23%; the remainder is aliphatics).
Aromatic C11-C22 (unadjusted)	22%	Based on IDEM, 2006 and supported by ATSDR, 1995 and data in Attachment A (average total aromatics is 23%; the remainder is aliphatics).
Carcinogenic PAHs	0.36%	Based on data in Attachment A
Naphthalenes	6.0%	Based on data in Attachment A
Aromatic C11-C22 (adjusted)	15.6%	Unadjusted value with percentage cPAHs and naphthalenes subtracted.

Cleanup Value by Percent Weight of Each Constituent

	Leaching Concentration (mg/Kg)	Leaching Concentration by Percent Weight [a] (mg/Kg)
Aliphatic C9-C18	--	--
Aromatic C11-C22 (unadjusted)	460	2,091
Carcinogenic PAHs	--	--
Naphthalenes	1.7	28
Aromatic C11-C22 (adjusted)	460	2,941

$$\text{Cleanup Level} = \text{Min}\left(\frac{\text{Leaching Concentration}}{\text{Percent Weight}}\right)$$

Cleanup Values for DRO/GRO

	DRO/GRO Cleanup Level with TAL Data Available [b] (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable [c] (mg/kg)
Leaching to Groundwater	2,941	28

[a] (Leaching Concentration) / (Percent Weight)
[b] Lowest leaching concentration by weight of any EPH/VPH fraction; adjusted values are used when TAL data are available.
[c] Lowest leaching concentration by weight of any EPH/VPH fraction and TAL parameter.

TAL = Target Analyte List
mg/kg = milligrams per kilogram

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological profile for fuel oils. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
IDEM, 2006. RISC Technical Guide - Chapter 8. June 15.

Prepared by/Date: KJC 03/17/10
Checked by/Date: JHP 03/18/10

Table 10
Number 6 Oil - Derivation of Leaching Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
C11-C22 Aromatics (unadjusted)	70%	MassDEP, 2002
C9-C18 Aliphatics	30%	MassDEP, 2002
Carcinogenic PAHs	0.33%	Based on data in Attachment A
Naphthalenes	2.6%	Based on data in Attachment A
Aromatic C11-C22 (adjusted)	67%	Unadjusted value with percentage cPAHs and naphthalenes subtracted.

Cleanup Value by Percent Weight of Each Constituent

	Leaching Concentration (mg/Kg)	Leaching Concentration by Percent Weight [a] (mg/Kg)
Aliphatic C9-C18	--	--
Aromatic C11-C22 (unadjusted)	460	657
Naphthalenes	1.7	65
Aromatic C11-C22 (adjusted)	460	686

$$\text{Cleanup Level} = \text{Min}\left(\frac{\text{Leaching Concentration}}{\text{Percent Weight}}\right)$$

Cleanup Values for DRO/GRO

	DRO/GRO Cleanup Level with TAL Data Available [b] (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable [c] (mg/kg)
Leaching to Groundwater	686	65

[a] (Leaching Concentration) / (Percent Weight)
[b] Lowest leaching concentration by weight of any EPH/VPH fraction; adjusted values are used when TAL data are available.
[c] Lowest leaching concentration by weight of any EPH/VPH fraction and TAL parameter.

TAL = Target Analyte List
mg/kg = milligrams per kilogram

Massachusetts Department of Environmental Protection (MassDEP), 2002. "Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MADEP EPH/VPH Approach". Final Policy #WSC-020411. October 31.

Prepared by/Date: KJC 03/17/10
Checked by/Date: JHP 03/18/10

Table 11
Used Crankcase Oil - Derivation of Leaching Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
Aliphatic C9-C18	72%	Based on aliphatics from ATSDR, 1997; supported by sum of alkanes (80%) from Attachment A
Aromatic C11-C22 (unadjusted)	28%	Based on sum of aromatics (sum of maximum) from ATSDR, 1997; supported by total aromatics value (22%) from Attachment A
Carcinogenic PAHs	0.042%	Based on data in Attachment A
Naphthalenes	3.2%	Based on data in Attachment A
Aromatic C11-C22 (adjusted)	24.8%	Unadjusted value with percentage cPAHs and naphthalenes subtracted.

Cleanup Value by Percent Weight of Each Constituent

	Leaching Concentration (mg/Kg)	Leaching Concentration by Percent Weight [a] (mg/Kg)
Aliphatic C9-C18	--	--
Aromatic C11-C22 (unadjusted)	460	1,643
Carcinogenic PAHs	--	--
Naphthalenes	1.7	53
Aromatic C11-C22 (adjusted)	460	1,858

$$\text{Cleanup Level} = \text{Min}\left(\frac{\text{Leaching Concentration}}{\text{Percent Weight}}\right)$$

Cleanup Values for DRO/GRO

	DRO/GRO Cleanup Level with TAL Data Available [b] (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable [c] (mg/kg)
Leaching to Groundwater	1,858	53

[a] (Leaching Concentration) / (Percent Weight)
[b] Lowest leaching concentration by weight of any EPH/VPH fraction; adjusted values are used when TAL data are available.
[c] Lowest leaching concentration by weight of any EPH/VPH fraction and TAL parameter.

TAL = Target Analyte List
mg/kg = milligrams per kilogram

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. Toxicological profile for used mineral-based crankcase oil. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Prepared by/Date: KJC 03/17/10
Checked by/Date: JHP 03/18/10

Table 12
Stoddard Solvent - Derivation of Leaching Based Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

Parameter	Percent Weight	Source
Aliphatic C5-C8	20%	Based on Air Force, 1989. Assumes 80% alkanes; 20% of which are in the C5-C8 range
Aliphatic C9-C18	60%	Based on Air Force, 1989. Assumes 80% alkanes; 20% of which are in the C5-C8 range
Aromatic C11-C22	20%	Based on Air Force, 1989.

Cleanup Value by Percent Weight of Each Constituent

	Leaching Concentration (mg/Kg)	Leaching Concentration by Percent Weight [a] (mg/Kg)
Aliphatic C5-C8	1600	8,000
Aliphatic C9-C18	--	--
Aromatic C11-C22 (unadjusted)	460	2,300

$$\text{Cleanup Level} = \text{Min}\left(\frac{\text{Leaching Concentration}}{\text{Percent Weight}}\right)$$

Cleanup Values for DRO/GRO

	DRO/GRO Cleanup Level with TAL Data Available [b] (mg/kg)	DRO/GRO Cleanup Level with TAL Data Unavailable [c] (mg/kg)
Leaching to Groundwater	2,300	--

[a] (Leaching Concentration) / (Percent Weight)
[b] Lowest leaching concentration by weight of any EPH/VPH fraction; adjusted values are used when TAL data are available.
[c] Lowest leaching concentration by weight of any EPH/VPH fraction and TAL parameter.

-- = TAL data not available.
TAL = Target Analyte List
mg/kg = milligrams per kilogram

Air Force. 1989. Gasoline. In: The installation restoration program toxicology guide. Volume 4. Contract no. DE-AC05-840R21400. Wright-Patterson Air Force Base, OH. Document no. 65-I-65-46.

Prepared by/Date: KJC 03/17/10
Checked by/Date: JHP 03/18/10

Table 13
Summary of Cleanup Levels

Derivation of Cleanup Levels for GRO and DRO

				Using Ceiling of 10,000	
Product	**Receptor**	**DRO/GRO Cleanup Level With Available TAL Data (mg/kg)**	**DRO/GRO Cleanup Level With Unavailable TAL Data (mg/kg)**	**DRO/GRO Cleanup Level With Available TAL Data (mg/kg)**	**DRO/GRO Cleanup Level With Unavailable TAL Data (mg/kg)**
Gasoline	Resident	5,232	2,216	5,155	2,170
	Park Visitor	8,720	3,694	7,902	3,436
	Construction Worker	37,838	1,870	10,000	1,654
	Outdoor Commercial Worker	40,088	11,423	10,000	6,379
	Leaching-Based Cleanup Level	469	10	469	10
No. 2 Fuel Oil	Resident	8,358	72	7,231	72
	Park Visitor	13,930	120	8,758	120
	Construction Worker	32,510	2,031	10,000	1,792
	Outdoor Commercial Worker	54,613	935	10,000	872
	Leaching-Based Cleanup Level	2,941	28	2,941	28
No. 6 Oil	Resident	4,658	78	4,507	78
	Park Visitor	7,763	130	6,891	130
	Construction Worker	26,326	3,588	10,000	2,950
	Outdoor Commercial Worker	28,928	1,015	10,000	954
	Leaching-Based Cleanup Level	686	65	686	65
Used Crankcase Oil	Resident	7,603	574	6,723	569
	Park Visitor	12,672	957	8,471	923
	Construction Worker	31,583	4,117	10,000	3,233
	Outdoor Commercial Worker	49,157	6,479	10,000	4,307
	Leaching-Based Cleanup Level	1,858	53	1,858	53
Stoddard Solvent	Resident	7,702	--	6,935	--
	Park Visitor	12,836	--	8,858	--
	Construction Worker	35,337	--	10,000	--
	Outdoor Commercial Worker	54,280	--	10,000	--
	Leaching-Based Cleanup Level	2,300	--	2,300	--
Unknown GRO	Resident	3,710	--	3,710	--
	Park Visitor	6,183	--	6,183	--
	Construction Worker	27,489	--	10,000	--
	Outdoor Commercial Worker	25,326	--	10,000	--
	Leaching-Based Cleanup Level	75	--	75	--
Unknown DRO	Resident	3,649	--	3,649	--
	Park Visitor	6,081	--	6,081	--
	Construction Worker	23,529	--	10,000	--
	Outdoor Commercial Worker	22,356	--	10,000	--
	Leaching-Based Cleanup Level	460	--	460	--

-- = Unable to calculate value due to lack of data.
TAL = Target Analyte List
mg/kg = milligrams per kilogram

Prepared by / Date: KJC 03/17/10
Checked by / Date: JHP 03/18/10

Calculation of cleanup values are presented in Tables 2 through 6 and 8 through 12.

FIGURES

Data File: \\target_server\GG\chem\gc10.i\GC10BD08A1.b\ABD1093.d
Date : 08-APR-2008 14:20
Client ID:
Instrument: gc10.i
Sample Info: DROA021A,M,GC10BD08A1,B,1,PHC 50UG/ML
Purge Volume: 1.0
Operator: JLP
Column phase: ZB-1
Column diameter: 0.53

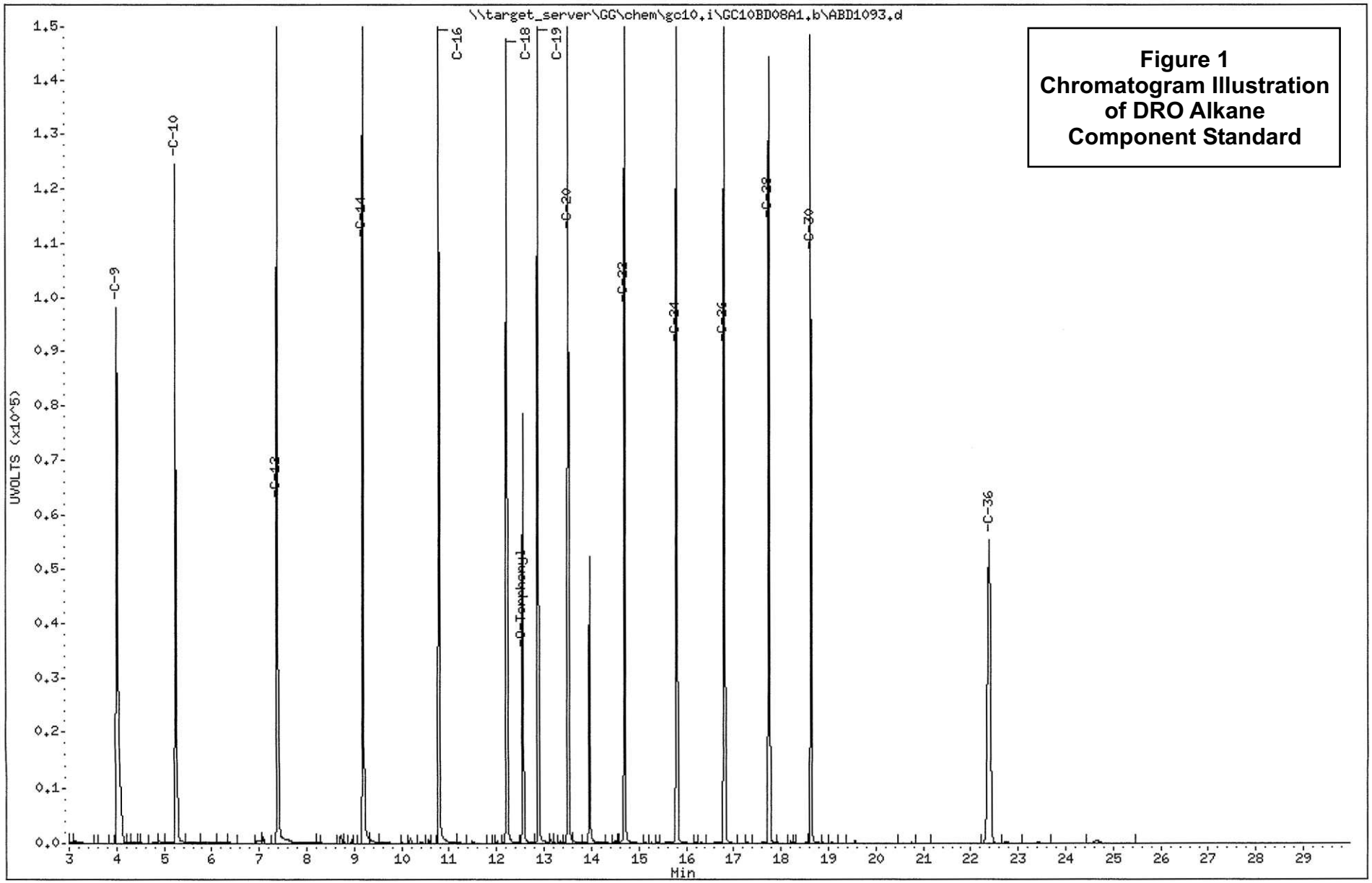

Figure 1
Chromatogram Illustration of DRO Alkane Component Standard

Chromatograms provided by Katahdin Analytical Services

PORT2008034a.cdr

Data File: \\Target_server\GG\chem\gc10.i\GC10BD09A1.b\ABD1160.d
Date : 10-APR-2008 10:31
Client ID:
Instrument: gc10.i
Sample Info: DROA021A,M,GC10BD09A1,B,1,GASOLINE
Purge Volume: 1.0
Operator: JLP
Column phase: ZB-1
Column diameter: 0.53

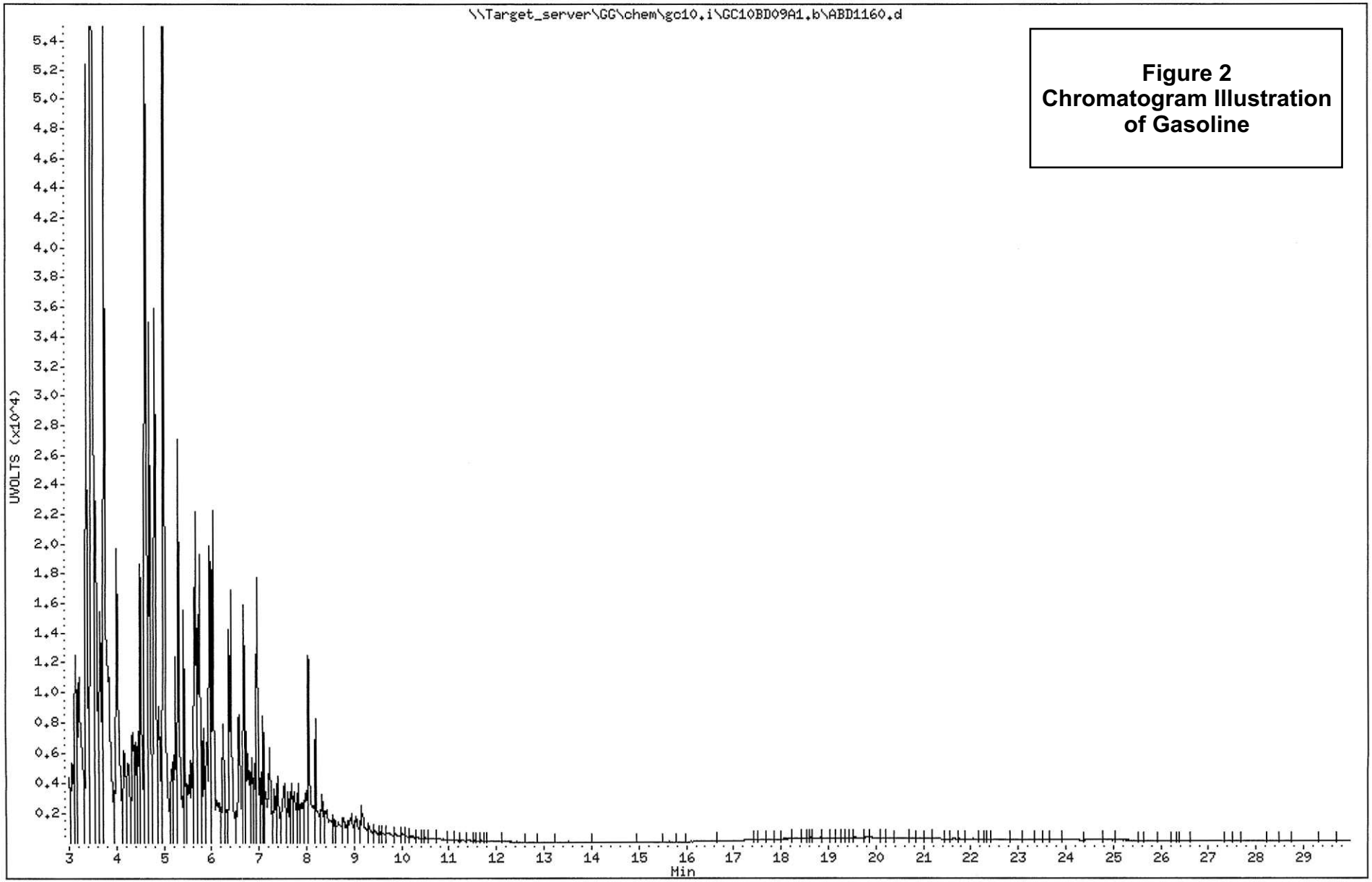

Figure 2
Chromatogram Illustration of Gasoline

Chromatograms provided by Katahdin Analytical Services

PORT2008034a.cdr

Data File: \\Target_server\GG\chem\gc10.i\GC10BD09A1.b\ABD1161.d
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Client ID:
Instrument: gc10.i
Sample Info: DROA021A,M,GC10BD09A1,B,1,KEROSENE
Purge Volume: 1.0
Operator: JLP
Column phase: ZB-1
Column diameter: 0.53

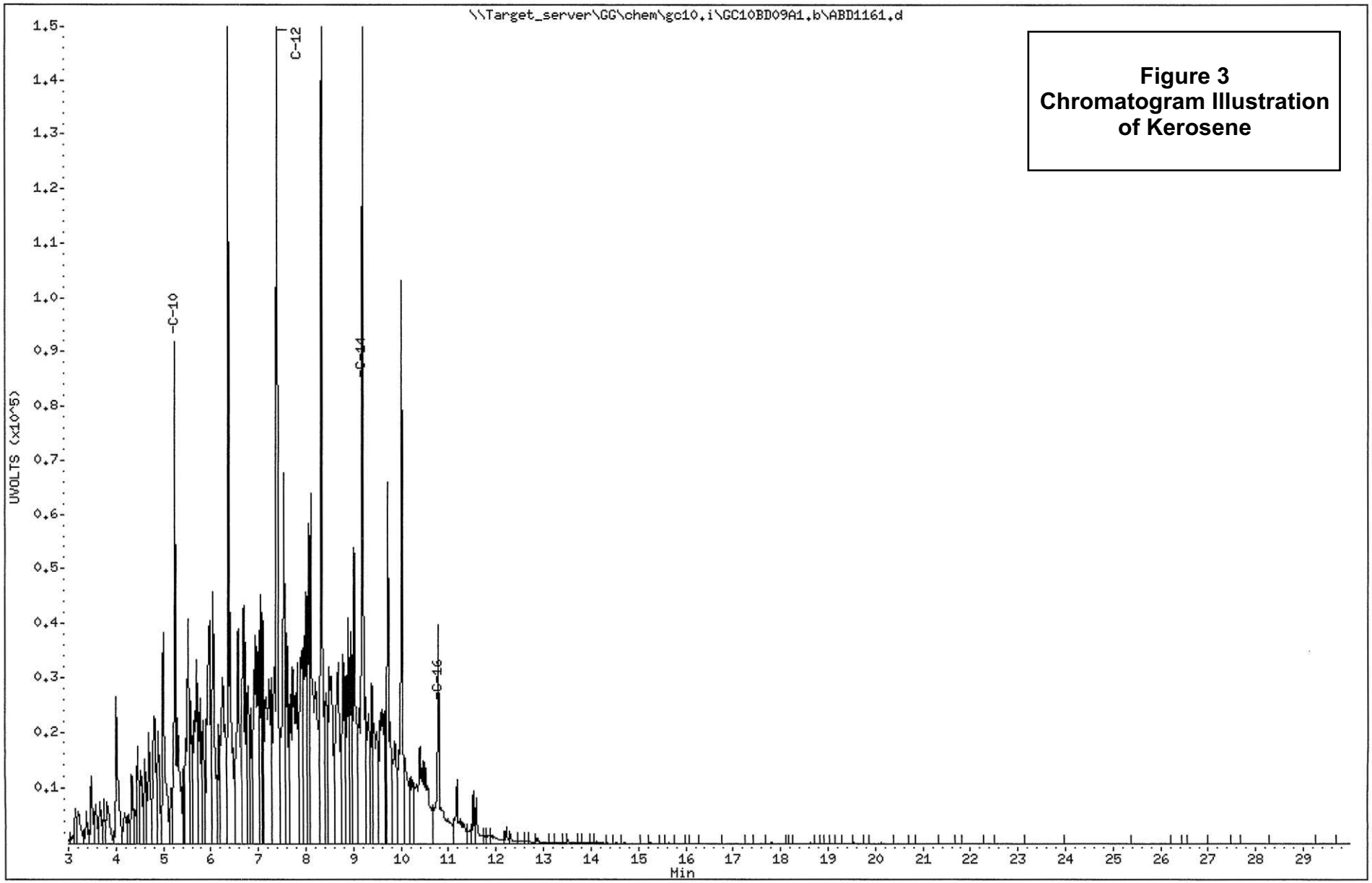

Figure 3
Chromatogram Illustration of Kerosene

Chromatograms provided by Katahdin Analytical Services

PORT2008034a.cdr

Data File: \\Target_server\GG\chem\gc10.i\GC10BD09A1.b\ABD1162.d
Date : 10-APR-2008 11:47
Client ID:
Instrument: gc10.i
Sample Info: DROA021A,M,GC10BD09A1,B,1,MINERAL SPIRIT
Purge Volume: 1.0
Operator: JLP
Column phase: ZB-1
Column diameter: 0.53

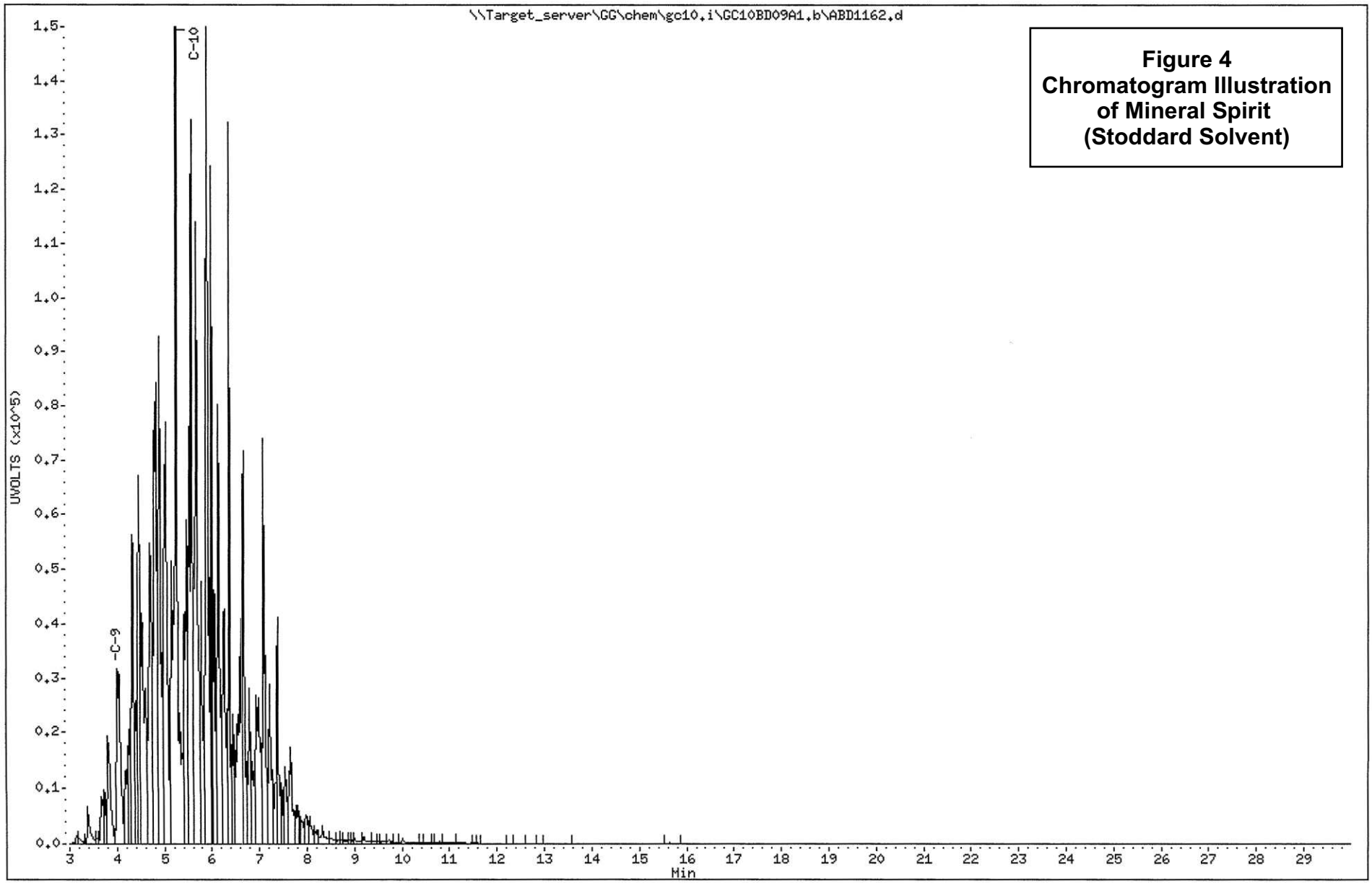

Figure 4
Chromatogram Illustration of Mineral Spirit (Stoddard Solvent)

Chromatograms provided by Katahdin Analytical Services

PORT2008034a.cdr

Data File: \\Target_server\GG\chem\gc10.i\GC10BD09A1.b\ABD1157.d
Date : 10-APR-2008 08:37
Client ID:
Instrument: gc10.i
Sample Info: DROA021A.M,GC10BD09A1.B,1,FO #2
Purge Volume: 1.0
Operator: JLP
Column phase: ZB-1
Column diameter: 0.53

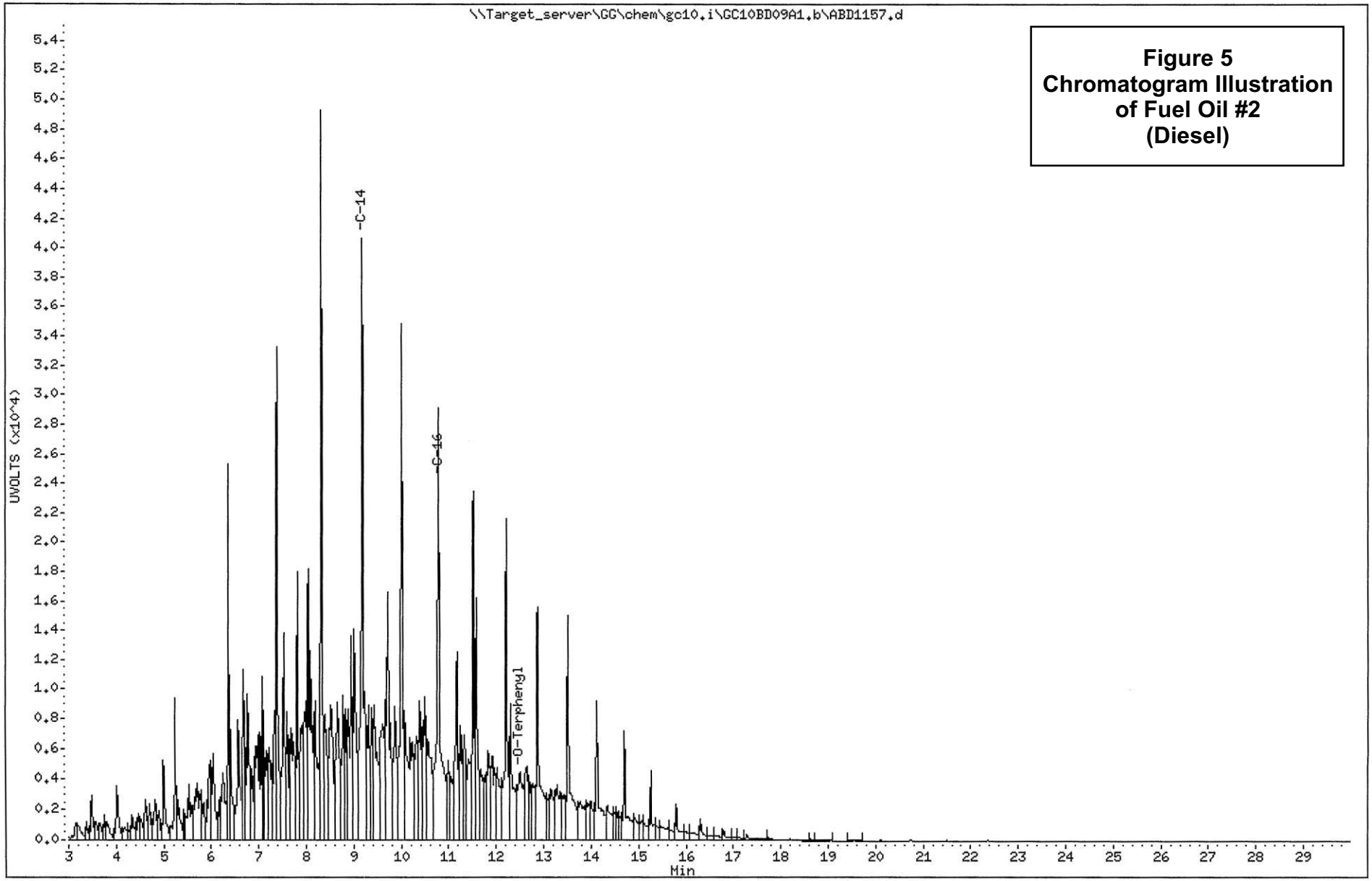

Figure 5
Chromatogram Illustration of Fuel Oil #2 (Diesel)

Chromatograms provided by Katahdin Analytical Services

PORT2008034a.cdr

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Client ID:
Instrument: gc10.i
Sample Info: DROA021A,M,GC10BD09A1,B,1,FO #4
Purge Volume: 1.0
Operator: JLP
Column phase: ZB-1
Column diameter: 0.53

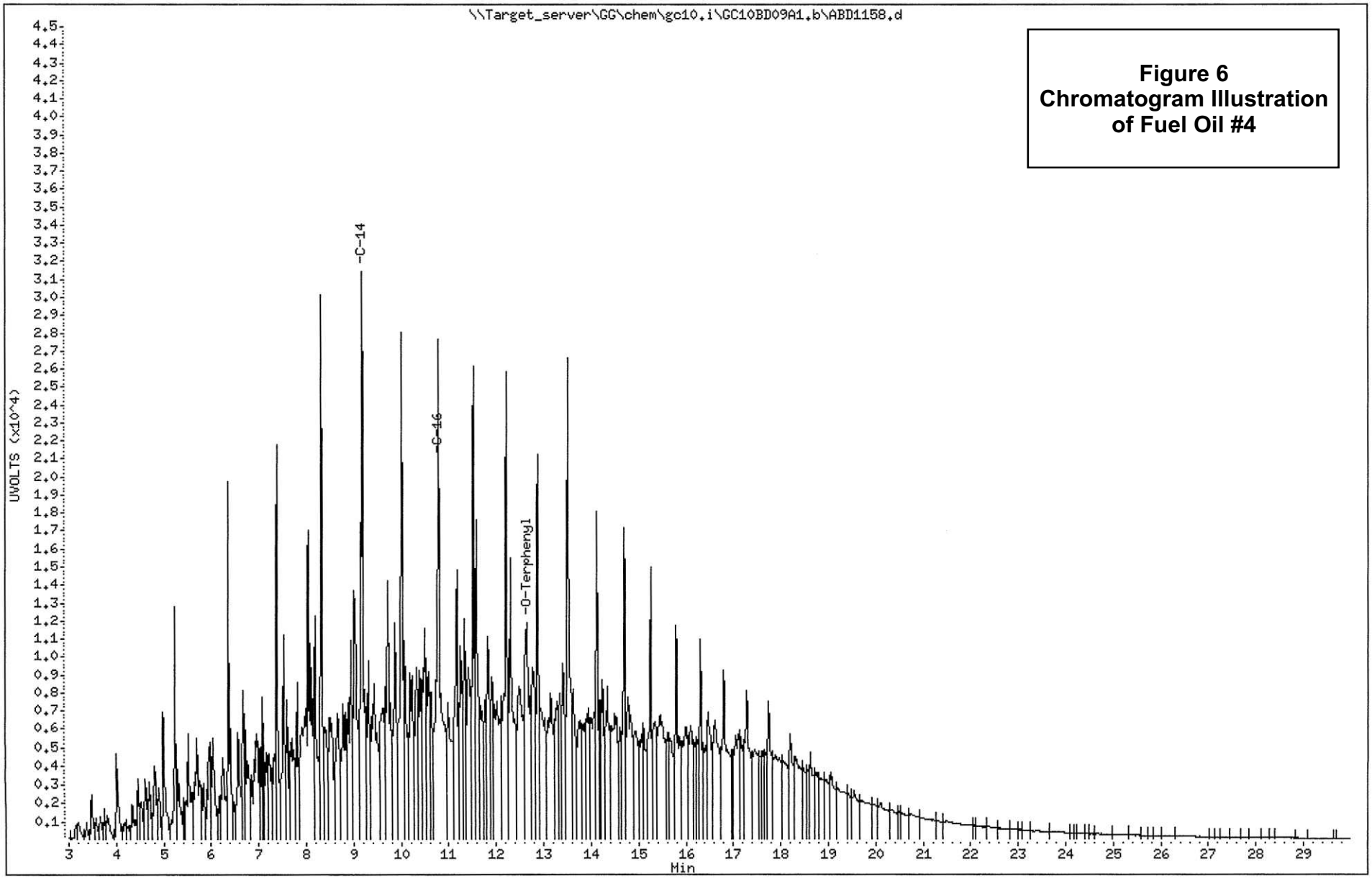

Figure 6
Chromatogram Illustration of Fuel Oil #4

Chromatograms provided by Katahdin Analytical Services

PORT2008034a.cdr

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Client ID:
Instrument: gc10.i
Sample Info: DROA021A.M,GC10BD09A1.B,1,FO #6
Purge Volume: 1.0
Operator: JLP
Column phase: ZB-1
Column diameter: 0.53

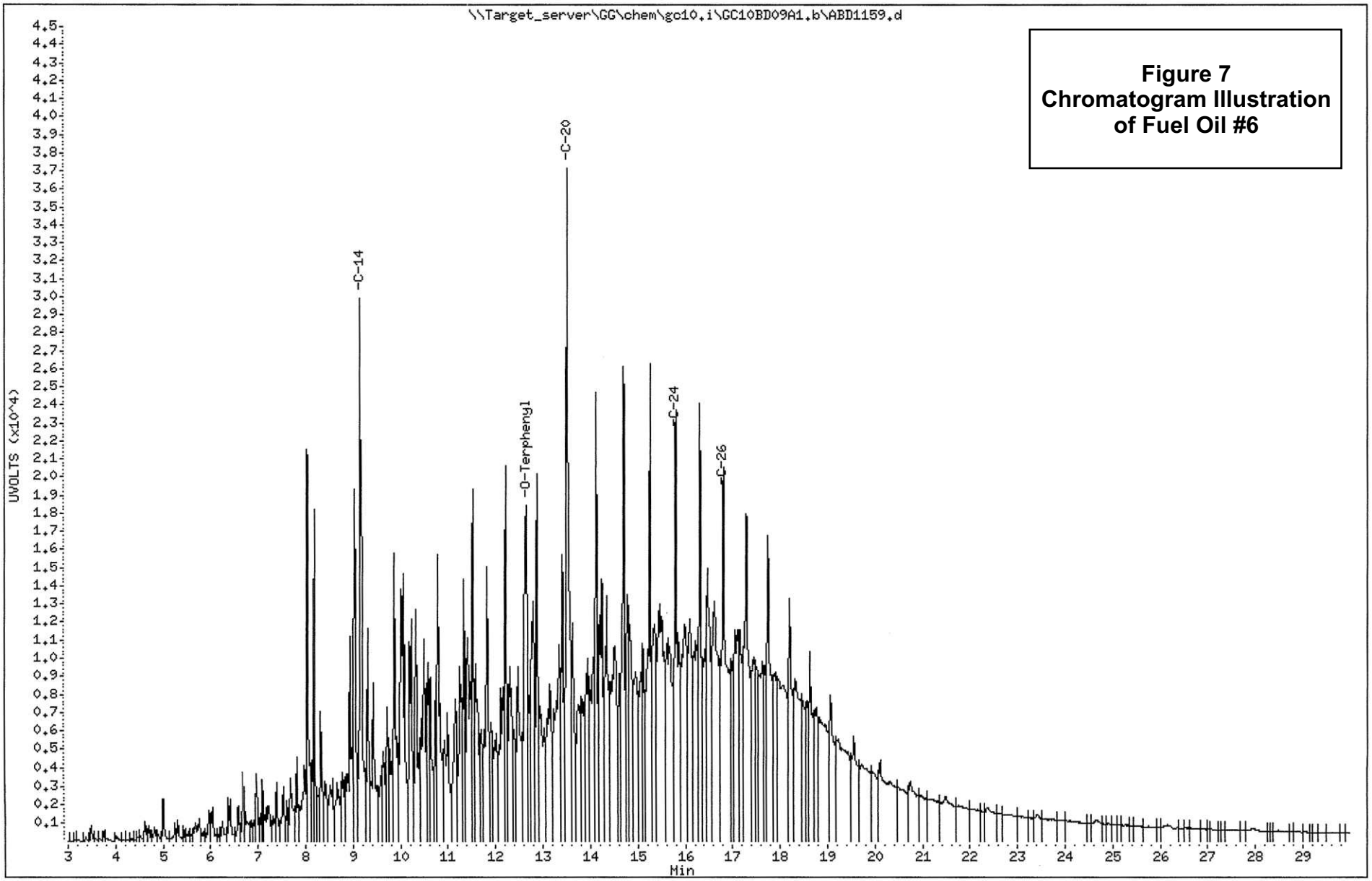

Figure 7
Chromatogram Illustration of Fuel Oil #6

Chromatograms provided by Katahdin Analytical Services

PORT2008034a.cdr

Data File: \\Target_server\GG\chem\gc10.i\GC10BD09A1.b\ABD1163.d
Date : 10-APR-2008 12:25
Client ID:
Instrument: gc10.i
Sample Info: DROA021A.M,GC10BD09A1.B,1,MOTOR OIL
Purge Volume: 1.0
Operator: JLP
Column phase: ZB-1
Column diameter: 0.53

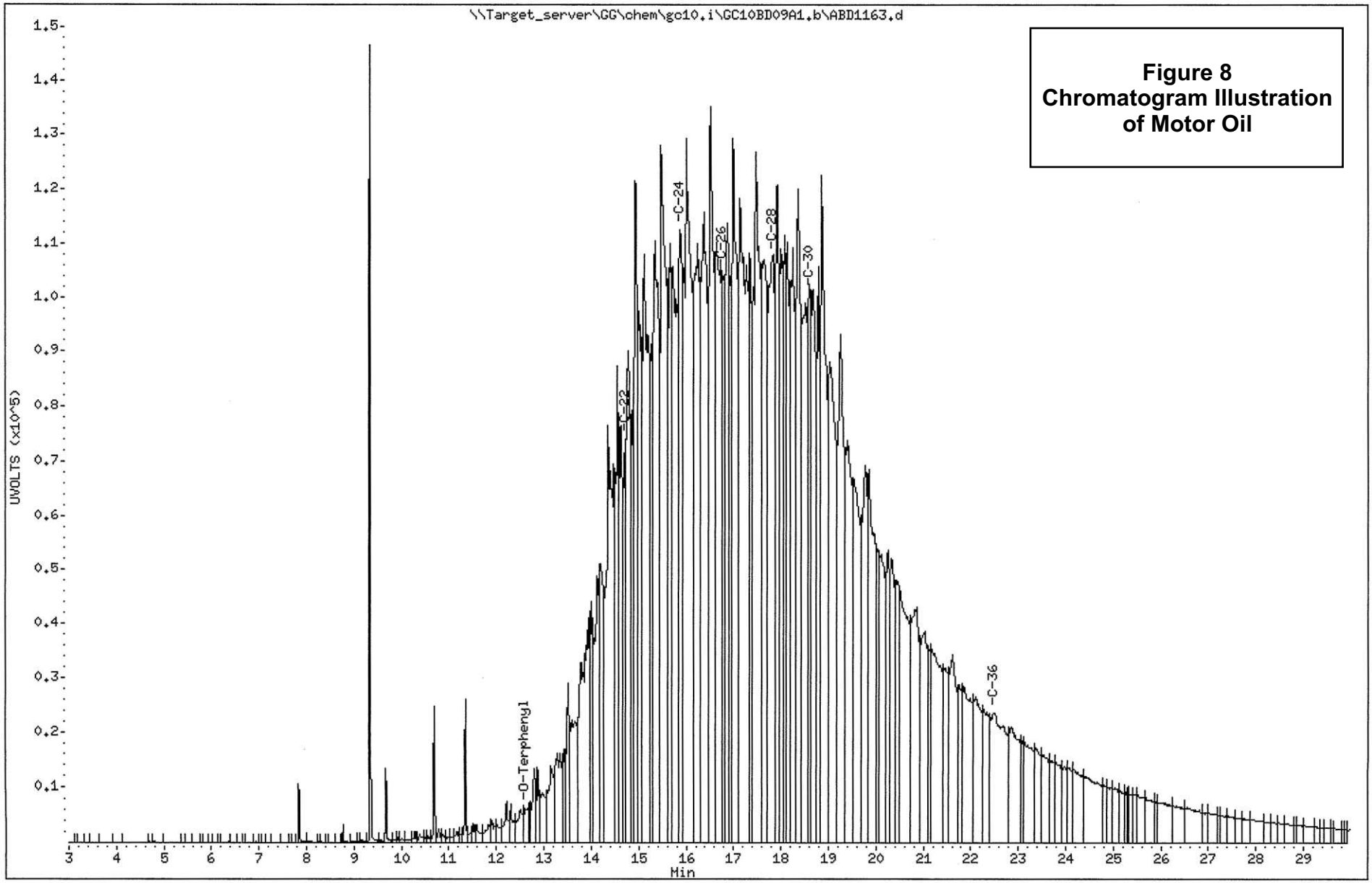

Figure 8
Chromatogram Illustration of Motor Oil

Chromatograms provided by Katahdin Analytical Services

PORT2008034a.cdr

Attachment A

Composition of Petroleum Products

Table 1A
Composition of Gasoline

Derivation of Cleanup Levels for GRO and DRO

Air Force, 1989	Percent Composition	Correlates to MADEP Fraction:
N-alkanes	15% - 17%	aliphatic
Cycloalkanes	3% - 5%	aliphatic
Benzenes and Alkylbenzenes	20% - 49%	>C6 aromatics
Branched alkanes	28% - 36%	aliphatic
Olefins	1% - 11%	>C18 aliphatic
Naphthalenes	0 - <1%	>C22 aromatic

Range of C4 to C11
49% to 62% aliphatic hydrocarbons

ATSDR, 1995	Percent Composition	Correlates to MADEP Fraction:
alkanes	4% - 8%	aliphatic
alkenes	2% - 5%	aliphatic
Isoalkanes	25% - 40%	aliphatic
cycloalkanes	3% - 7%	aliphatic
total aromatics	20% - 50%	aromatic
Benzene	0.5% - 2.5%	benzene

MassDEP, 2002
Conservative assumption would be to consider all of the non-BTEXT/MTBE hydrocarbons greater than C8 to be C9-C10 Aromatics.

IDEM, 2006	Percent Composition	Correlates to MADEP Fraction:
Aliphatic C5-C6	23%	C5-C8 aliphatic
Aliphatic C6-C8	22%	C5-C8 aliphatic
Aliphatic C8-C10	9%	C9-C18 aliphatic
Aliphatic C10-C12	3%	C9-C18 aliphatic
Aromatic C8-C10	41%	C9-C10 aromatic
Aromatic C10-C12	2%	C10-C12 aromatic

Composition for Derivation of Cleanup Levels

Aliphatic C5-C8	45%	Based on IDEM, 2006; supported by Air Force, ATSDR, and data in Table 1B
Aliphatic C9-C18	12%	Based on IDEM, 2006
Aromatic C9-C10 (unadjusted)	43%	Based on IDEM, 2006; supported by Air Force, ATSDR, and data in Table 1B
Benzene	2%	Based on data in Table 1B
Ethylbenzene	8%	Based on data in Table 1B
Toluene	2%	Based on data in Table 1B
Xylenes	9%	Based on data in Table 1B
Naphthalenes	6%	Based on data in Table 1B
Aromatic C9-C10 (adjusted)	16%	Unadjusted value with percentage ethylbenzene, toluene, xylenes, and naphthalenes subtracted.

Air Force. 1989. Gasoline. In: The installation restoration program toxicology guide. Volume 4.
Contract no. DE-AC05-840R21400. Wright-Patterson Air Force Base, OH. Document no. 65-I-65-46.

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological profile for automotive gasoline.
Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Massachusetts Department of Environmental Protection (MassDEP), 2002. "Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MADEP EPH/VPH Approach". Final Policy #WSC-020411. October 31.

Indiana DEM, 2006. RISC Technical Guide. June 15.

Table 1B
Summary of Composition Data for Gasoline

Derivation of Cleanup Levels for GRO and DRO

compound class	carbon #	compound	average wt %*	minimum*	maximum*	stdev*	coefficient of variation*	total number of data points
Alkenes		Total Alkenes	1.00E+01	8.40E+00	1.20E+01	2.20E+00	2.20E+01	124
	4	1,3-Butadiene	3.70E-03	1.00E-03	6.00E-03	8.90E-04	2.40E+01	124
	4	cis-2-Butene	3.10E-01	2.00E-01	4.50E-01	6.80E-02	2.20E+01	124
	4	trans-2-Butene	3.60E-01	2.30E-01	5.30E-01	7.90E-02	2.30E+01	124
	5	2-Methyl-1-butene	5.40E-01	4.80E-01	6.20E-01	1.10E-01	2.10E+01	124
	5	2-Methyl-2-butene	1.10E+00	9.70E-01	1.20E+00	2.20E-01	2.10E+01	124
	5	cis-2-Pentene	3.90E-01	3.50E-01	4.40E-01	8.00E-02	2.10E+01	124
	5	trans-2-Pentene	7.20E-01	6.50E-01	8.00E-01	1.50E-01	2.10E+01	124
Alkyl-Monoaromatics	6	Benzene	1.90E+00	1.60E+00	2.30E+00	4.10E-01	2.20E+01	124
	7	Toluene	8.10E+00	6.40E+00	1.00E+01	1.80E+00	2.20E+01	124
	8	Ethylbenzene	1.70E+00	1.40E+00	2.00E+00	3.70E-01	2.20E+01	124
	8	m-Xylene	4.60E+00	3.90E+00	5.40E+00	1.00E+00	2.20E+01	124
	8	o-Xylene	2.50E+00	2.10E+00	3.10E+00	5.60E-01	2.20E+01	124
	8	p-Xylene	1.90E+00	1.60E+00	2.30E+00	4.10E-01	2.20E+01	124
	9	1,2,4-Trimethylbenzene	3.00E+00	2.50E+00	3.30E+00	6.50E-01	2.20E+01	124
	9	1,3,5-Trimethylbenzene	9.80E-01	8.40E-01	1.10E+00	2.10E-01	2.20E+01	124
	9	1-Methyl-2-ethylbenzene	7.10E-01	6.20E-01	7.80E-01	1.60E-01	2.20E+01	124
	9	1-Methyl-3-ethylbenzene	1.80E+00	1.50E+00	2.00E+00	4.00E-01	2.20E+01	124
	9	1-Methyl-4-ethylbenzene	8.00E-01	6.60E-01	9.10E-01	1.80E-01	2.20E+01	124
Branched Alkanes	4	Isobutane	1.70E+00	8.00E-01	2.60E+00	4.10E-01	2.40E+01	124
	5	Isopentane	7.90E+00	7.10E+00	8.80E+00	1.70E+00	2.20E+01	124
	6	2,2-Dimethylbutane	4.90E-01	4.00E-01	6.40E-01	1.10E-01	2.20E+01	124
	6	2,3-Dimethylbutane	1.00E+00	9.70E-01	1.10E+00	2.20E-01	2.10E+01	124
	6	2-Methylpentane	3.90E+00	3.20E+00	4.50E+00	8.40E-01	2.20E+01	124
	6	3-Methylpentane	2.50E+00	2.10E+00	2.90E+00	5.40E-01	2.20E+01	124
	7	2,4-Dimethylpentane	8.30E-01	5.60E-01	1.20E+00	1.90E-01	2.30E+01	124
Branched Alkanes (continued)	7	2-Methylhexane	3.00E+00	2.50E+00	3.80E+00	6.50E-01	2.20E+01	124
	7	3-Methylhexane	1.70E+00	1.60E+00	1.90E+00	3.70E-01	2.10E+01	124
	8	2,2,4-Trimethylpentane	2.40E+00	8.70E-01	4.20E+00	5.90E-01	2.50E+01	124
	8	2,3,3-Trimethylpentane	6.60E-01	2.00E-01	1.30E+00	1.70E-01	2.60E+01	124
	8	2,3,4-Trimethylpentane	9.70E-01	3.50E-01	1.80E+00	2.40E-01	2.50E+01	124
	8	2,3-Dimethylhexane	3.90E-01	2.50E-01	5.80E-01	8.90E-02	2.30E+01	124
	8	2,4-Dimethylhexane	4.40E-01	3.10E-01	6.10E-01	9.70E-02	2.20E+01	124
	8	3-Methylheptane	7.50E-01	6.20E-01	8.70E-01	1.60E-01	2.20E+01	124
Cycloalkanes	5	Cyclopentane	4.70E-01	3.40E-01	6.10E-01	1.10E-01	2.20E+01	124
	6	Cyclohexane	3.90E-01	2.30E-01	6.00E-01	9.30E-02	2.30E+01	124
	6	Methylcyclopentane	1.80E+00	1.40E+00	2.30E+00	4.00E-01	2.20E+01	124
	7	Methylcyclohexane	5.80E-01	3.90E-01	7.50E-01	1.30E-01	2.20E+01	124
n-Alkanes	4	n-Butane	4.70E+00	2.60E+00	6.50E+00	1.10E+00	2.30E+01	124
	5	n-Pentane	3.90E+00	3.00E+00	4.90E+00	8.60E-01	2.20E+01	124
	6	n-Hexane	2.40E+00	1.80E+00	3.20E+00	5.30E-01	2.20E+01	124
	7	n-Heptane	1.10E+00	1.00E+00	1.20E+00	2.40E-01	2.10E+01	124
Naphthalenes		Total Naphthalenes	5.80E+00	4.10E+00	7.20E+00	1.30E+00	2.20E+01	124
	10	Naphthalene	2.50E-01	1.50E-01	3.60E-01	5.70E-02	2.20E+01	124
	11	1-Methylnaphthalene	7.00E-02	4.00E-02	1.10E-01	1.60E-02	2.30E+01	124
	11	2-Methylnaphthalene	1.80E-01	1.00E-01	2.90E-01	4.30E-02	2.30E+01	124
Oxygenates	5	Methyl-ter t-butylether	3.30E-01	1.00E-02	7.90E-01	1.00E-01	2.70E+01	124
Total Aromatics		Total Aromatics	3.50E+01	2.90E+01	3.80E+01	7.50E+00	2.20E+01	124
Total Monoaromatics		Total Benzene, Toluene and Xylenes	1.90E+01	1.60E+01	2.40E+01	4.20E+00	2.20E+01	124
Total Straight-Chain and Branched Alkanes		Total Straight-Chain and Branched Alkanes	4.70E+01	4.50E+01	5.00E+01	1.00E+01	2.10E+01	124

Source: Thomas L. Potter; Kathleen E. Simmons, "Volume 2:Composition of Petroleum Mixtures". 1998, ISBN 1-884-940-19-6

Table 2A
Composition of Fuel Oil No. 2

Derivation of Cleanup Levels for GRO and DRO

ATSDR, 1995
Range of C11 to C20

	Volume %	Correlates to MADEP Fraction:
Paraffins	41.3	>C11 aliphatics
Monocycloparaffins	22.1	>C11 aliphatics
Bicycloparaffins	9.6	>C11 aliphatics
Tricycloparaffins	2.3	>C11 aliphatics
Total saturated hydrocarbons	75.3	
Olefins	ND	
Alkylbenzenes	5.9	C11-C22 aromatcs
Indans/tetralins	4.1	C11-C22 aromatcs
Dinaphthenobenzenes/indenes	1.8	C11-C22 aromatcs
Naphthalenes	8.2	C11-C22 aromatcs
Biphenyls/acenaphthenes	2.6	C11-C22 aromatcs
Fluorenes/acenaphthylenes	1.4	C11-C22 aromatcs
Phenanthrenes	0.7	C11-C22 aromatcs
Total aromatic hydrocarbons	24.7	C11-C22 aromatcs

Mass DEP, 2008	Percent
C11-C22 Aromatics	60
C9-C18 Aliphatics	40
C19-C36 Aliphatics	0

IDEM, 2006

	Percent in Diesel	Correlates to MADEP Fraction:
Aliphatic C5-C6	0.06	C5-C8 aliphatic
Aliphatic C6-C8	0.31	C5-C8 aliphatic
Aliphatic C8-C10	1.02	C9-C18 aliphatic
Aliphatic C10-C12	4.18	C9-C18 aliphatic
Aliphatic C12-C16	30	C9-C18 aliphatic
Aliphatic C16-C21	42.6	C9-C18 aliphatic
Aliphatic C21-C36	0	C19-C36 aliphatic
Aromatic C8-C10	0.94	C9-C10 aromatic
Aromatic C10-C12	3.53	C11-C22 aromatic
Aromatic C12-C16	9.68	C11-C22 aromatic
Aromatic C16-C21	7.61	C11-C22 aromatic
Aromatic C21-C36	0.07	N/A

Composition for Derivation of Cleanup Levels

Aliphatic C9-C18	78%	Based on IDEM, 2006 and supported by ATSDR and data in Table 2B (average total aromatics is 23%; the remainder is aliphatics).
Aromatic C11-C22	22%	Based on IDEM, 2006 and supported by ATSDR and data in Table 2B (average total aromatics is 23%; the remainder is aliphatics).
Carcinogenic PAHs	0.36%	Based on data in Table 2B for total PAHs
Naphthalenes	6%	Average of ATSDR and total naphthalene on Table 2B.

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological profile for fuel oils. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Massachusetts Department of Environmental Protection (MassDEP), 2002. "Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MADEP EPH/VPH Approach". Final Policy #WSC-020411. October 31.

Indiana DEM, 2006. RISC Technical Guide. June 15.

Table 2B
Summary of Composition Data for Fuel Oil No. 2

Derivation of Cleanup Levels for GRO and DRO

compound class	carbon #	compound	Average	Min	Max
Alkenes		Total Alkenes	1.38E+00	2.00E-01	2.20E+00
Alkyl-Monoaromatics		Total Alkyl-Monoaromatics	6.36E+00	1.80E+00	1.00E+01
	6	Benzene	2.90E-02	2.60E-03	1.00E-01
	7	Toluene	1.41E-01	6.90E-03	7.00E-01
	8	Ethylbenzene	5.95E-02	7.00E-03	2.00E-01
	8	m+p-Xylenes	2.20E-01	1.80E-02	5.10E-01
	8	o-Xylene	4.30E-02	1.20E-03	8.50E-02
	8	Total Xylenes	2.84E-01	1.50E-01	4.30E-01
	9	1,3,5-Trimethylbenzene	1.80E-01	9.00E-02	2.40E-01
	9	n-Propylbenzene	3.90E-02	3.00E-02	4.80E-02
	10	1-Methyl-4-isopropylbenzene	1.50E-02	3.00E-03	2.60E-02
	10	n-Butylbenzene	3.80E-02	3.10E-02	4.60E-02
Branched Alkanes	12	3-Methylundecane	1.70E-01	9.00E-02	2.80E-01
	13	2-Methyldodecane	2.80E-01	1.50E-01	5.20E-01
	14	3-Methyltridecane	1.90E-01	1.30E-01	3.00E-01
	15	2-Methyltetradecane	4.80E-01	3.40E-01	6.30E-01
	19	Pristane	6.00E-01	3.50E-01	8.10E-01
	20	Phytane	5.00E-01	3.50E-01	5.90E-01
Cycloalkanes		Total Dicycloalkanes	1.25E+01	3.70E+00	1.80E+01
		Total Monocycloalkanes	1.72E+01	5.00E+00	3.10E+01
		Total Tetracycloalkanes	1.00E-01	0.00E+00	0.00E+00
		Total Tricycloalkanes	5.22E+00	5.80E-01	1.30E+01
Diaromatics (Except Naphthalenes)		Total Fluorenes and Acenaphthylenes	1.10E+00	4.40E-01	2.00E+00
	12	Total Fluorenes	5.60E-01	3.00E-02	1.40E+00
	13	Biphenyl	3.51E-02	5.90E-03	1.20E-01
	13	Fluorene	7.02E-02	4.30E-03	1.50E-01
	14	Total Methylbiphenyls	5.30E-02	0.00E+00	0.00E+00
	15	Total Methylfluorenes	1.54E-01	1.50E-02	3.80E-01
		Total Dimethylfluorenes	1.61E-01	2.70E-02	3.50E-02
		Total Trimethylfluorenes	2.80E-02	1.90E-02	3.60E-02
Inorganics		Total Nitrogen	9.10E-03	7.00E-05	5.60E-02
		Total Sulfur	7.20E-02	4.10E-03	4.90E-01
		Water	5.20E-04	1.50E-04	7.30E-04
Metals		Nickel	5.00E-05	0.00E+00	0.00E+00
		Vanadium	1.50E-04	0.00E+00	0.00E+00
		Arsenic	7.10E-06	0.00E+00	0.00E+00
		Cadmium	4.90E-05	0.00E+00	0.00E+00
		Chromium	1.70E-04	0.00E+00	0.00E+00
		Iron	3.70E-03	0.00E+00	0.00E+00
		Manganese	3.20E-04	0.00E+00	0.00E+00
		Molybdenum	1.40E-05	0.00E+00	0.00E+00
		Zinc	3.10E-04	0.00E+00	0.00E+00
Monoaromatics	10	Total Benzocycloparaffins	6.30E+00	6.00E+00	6.60E+00
	8	Total Benzodicycloparaffins	3.00E+00	3.00E+00	3.00E+00
	9	Total Dinaphthenobenzenes	3.20E+00	0.00E+00	0.00E+00
	10	Total Dinaphthenobenzenes and Indenes	1.50E+00	1.30E+00	1.80E+00
	11	Total Indenes	2.89E+00	7.00E-01	5.60E+00
	12	Indene	1.90E-02	8.70E-03	2.90E-02
	13	Total Indans and Tetralins	5.68E+00	1.20E+00	1.00E+01
n-Alkanes	14	n-Decane and n-Undecane	1.30E+00	0.00E+00	0.00E+00
	15	n-Octane	1.05E-01	1.00E-01	1.30E-01
	16	n-Nonane	3.65E-01	1.90E-01	4.90E-01
	17	n-Decane	7.18E-01	2.80E-01	1.20E+00
	18	n-Undecane	1.28E+00	5.70E-01	2.30E+00
	19	n-Dodecane	1.52E+00	8.40E-01	2.50E+00
	20	n-Tridecane	1.95E+00	9.60E-01	2.80E+00
	21	n-Tetradecane	1.93E+00	6.10E-01	2.70E+00
	22	n-Pentadecane	2.54E+00	1.10E+00	3.20E+00
	24	n-Hexadecane	2.33E+00	1.00E+00	3.30E+00
		n-Heptadecane	2.26E+00	6.50E-01	3.60E+00
	10	n-Octadecane	1.66E+00	5.50E-01	2.50E+00
	11	n-Nonadecane	9.64E-01	3.30E-01	1.50E+00
	11	n-Eicosane	5.42E-01	1.80E-01	1.00E+00
	11	n-Heneicosane	3.68E-01	9.00E-02	8.30E-01
	12	n-Docosane	2.68E-01	1.40E-01	4.40E-01
	12	n-Tetracosane	3.50E-01	0.00E+00	0.00E+00
Naphthalenes	12	Total Naphthalenes	3.93E+00	4.10E-01	1.20E+01
	12	Naphthalene	2.50E-01	9.00E-03	8.00E-01
	13	1-Methylnaphthalene	4.62E-01	7.00E-04	8.10E-01
		2-Methylnaphthalene	8.20E-01	1.10E-03	1.50E+00
	11	Total Methylnaphthalenes	6.94E-01	6.40E-02	2.70E+00
	10	1,3-Dimethylnaphthalene	9.70E-01	5.50E-01	1.30E+00

Table 2B
Summary of Composition Data for Fuel Oil No. 2

Derivation of Cleanup Levels for GRO and DRO

compound class	carbon #	compound	Average	Min	Max
	12	1,4-Dimethylnaphthalene	1.50E-01	4.30E-02	2.30E-01
	13	1,5-Dimethylnaphthalene	2.90E-01	1.60E-01	3.60E-01
	13	Total Dimethylnaphthalenes	1.14E+00	1.50E-01	3.20E+00
	13	Total Trimethylnaphthalenes	3.90E-01	2.10E-02	1.80E+00
	13	Total Tetramethylnaphthalenes	3.30E-01	6.30E-02	5.90E-01
Polynuclear Aromatics	14	Total Acenaphthylenes	1.50E+00	6.00E-04	3.90E+00
		Total Acenaphthalenes	2.10E+00	3.00E-01	5.40E+00
	14	Total Acenaphthenes	1.92E+00	6.00E-02	5.40E+00
	14	Total Biphenyls and Acenaphthenes	2.13E+00	1.60E+00	2.30E+00
	14	Total Methylfluoranthenes and Pyrenes	5.40E-03	1.70E-03	9.10E-03
	14	Total Phenanthrenes	4.90E-01	1.70E-02	1.00E+00
	14	Total Tricyclicaromatics	3.00E-01	2.00E-01	4.00E-01
	15	Total Triaromatics	5.00E-01	7.00E-02	1.60E+00
	16	2-Aminoanthracene	4.00E-04	1.00E-04	5.00E-04
	16	2-Aminophenanthrene	2.40E-04	1.00E-04	4.00E-04
	18	3-Aminophenanthrene	2.00E-04	1.00E-04	3.00E-04
		4-Aminophenanthrene	3.40E-04	1.00E-04	6.00E-04
		Acenaphthene	1.80E-02	1.30E-02	2.20E-02
		Acenaphthylene	6.00E-03	0.00E+00	0.00E+00
		Anthracene	4.90E-03	3.00E-06	2.00E-02
		Phenanthrene	8.50E-02	2.70E-05	3.00E-01
	14	1-Methylphenanthrene	6.42E-03	1.10E-05	2.40E-02
	14	2-Methylanthracene	6.84E-03	1.50E-05	1.80E-02
	14	2-Methylphenanthrene	3.13E-01	1.40E-01	7.70E-01
	14	Methylanthracene	1.60E-03	6.60E-04	2.10E-03
	14	3-Methylphenanthrene	3.80E-03	1.30E-05	1.10E-02
	14	4- & 9-Methylphenanthrene	6.70E-03	1.30E-05	3.40E-02
	15	9-Cyanoanthracene	6.40E-04	3.00E-04	9.00E-04
	15	9-Cyanophenanthrene	6.80E-04	4.00E-04	1.00E-03
	15	Total Methylanthracenes	9.30E-04	0.00E+00	0.00E+00
	15	Total Methylphenanthrenes	2.63E-01	4.20E-02	7.90E-01
	15	9,10-Dimethylanthracene	3.90E-03	1.80E-03	6.00E-03
	15	Fluoranthene	4.21E-03	6.80E-07	2.00E-02
	15	Pyrene	3.96E-03	1.80E-05	1.50E-02
	15	Total Dimethylphenanthrenes	6.30E-02	2.00E-02	2.10E-01
	15	Total Trimethylphenanthrenes	5.10E-02	2.20E-02	8.00E-02
	16	1-Methylpyrene	2.90E-04	2.40E-06	1.40E-03
	16	2-Methylpyrene	2.80E-04	3.70E-06	1.10E-03
	16	Benzo(a)fluorene	2.80E-04	5.40E-07	1.30E-03
	17	1-Methyl-7-isopropylphenanthrene	6.60E-04	1.50E-06	4.00E-03
	17	Benz(a)anthracene	7.20E-05	2.00E-06	6.70E-04
	17	Benzo(g,h,i)fluoranthene	9.30E-05	2.50E-07	3.50E-04
	18	Chrysene	1.29E-04	3.70E-05	3.90E-04
	18	Total Tetramethylphenanthrenes	2.10E-02	8.70E-03	3.20E-02
	18	Chr ysene and Triphenylene	1.20E-04	8.40E-07	4.90E-04
	18	Triphenylene	1.38E-04	2.30E-05	1.40E-04
	18	Total Methylchrysenes	3.90E-04	9.10E-05	6.80E-04
	18	Benzo(a)pyrene	1.04E-04	1.00E-06	8.40E-04
	20	Benzo(b+k)fluoranthene	3.10E-05	3.10E-07	1.90E-04
	20	Benzo(e)pyrene	2.63E-05	2.00E-06	2.40E-04
	20	Benzo(g,h,i)pyrene	2.80E-06	1.00E-06	7.00E-06
	21	Cyclopenta(cd)pyrene	6.80E-05	1.60E-06	3.70E-04
	22	Benzo(g,h,i)perylene	1.13E-05	9.10E-07	4.00E-05
	22	Indeno(1,2,3-cd)pyrene	1.60E-05	6.40E-07	9.70E-05
	22	Picene	1.50E-05	3.50E-07	8.30E-05
		Total Dimethylchrysenes	2.30E-04	4.60E-05	4.20E-04
		Total Trimethylchrysenes	9.50E-05	9.10E-06	1.80E-04
Total Aromatics		Total Aromatics	2.29E+01	2.00E+00	3.90E+01
		Total Aromatics by HPLC	2.30E+01	8.70E+00	3.80E+01
Total Branched Alkanes		Total Branched Alkanes	2.20E+01	0.00E+00	0.00E+00
Total Cycloalkanes		Total Cycloalkanes	3.70E+01	5.30E+00	5.40E+01
Total Diaromatics (IncludingNaphthalenes)		Total Diaromatics (Including Naphthalenes)	6.30E+00	7.30E-02	2.00E+01
Total Monoaromatics		Total Monoaromatics	1.60E+01	3.70E+00	2.20E+01
Total n-Alkanes		Total n-Alkanes	1.35E+01	8.10E+00	3.30E+01
Total Polynuclear Aromatics		Total Polynuclear Aromatics	3.60E-01	1.50E-04	2.30E+00
Total Straight-Chain and Branched Alkanes		Total Straight-Chain and Branched Alkanes	4.35E+01	2.50E+01	7.50E+01

Source: Thomas L. Potter; Kathleen E. Simmons, "Volume 2:Composition of Petroleum Mixtures". 1998, ISBN 1-884-940-19-6

Table 3A
Composition of Fuel Oil No. 6

Derivation of Cleanup Levels for GRO and DRO

Mass DEP, 2002	Percent
C11-C22 Aromatics	70
C9-C18 Aliphatics	30
C19-C36 Aliphatics	0

Massachusetts Department of Environmental Protection (MassDEP), 2002. "Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MADEP EPH/VPH Approach". Final Policy #WSC-020411. October 31.

Composition for Derivation of Cleanup Levels

C11-C22 Aromatics	70%	MADEP, 2002
C9-C18 Aliphatics	30%	MADEP, 2002
Naphthalenes	2.6%	Table 3B total for naphthalene and methylnaphthalene
Carcinogenic PAHs	0.33%	Table 3B

Table 3B
Summary of Composition Data for No. 6 Fuel Oil

Derivation of Cleanup Levels for GRO and DRO

compound class	carbon #	compound	average wt %*	minimum*	maximum*	stdev*	coefficient of variation*	total number of data points
Alkyl-Monoaromatics		Total Alkyl-Monoaromatics	1.90E+00					1
Branched Alkanes	19	Pristane	5.10E-02	4.10E-02	6.20E-02			2
	20	Phytane	6.30E-02	5.50E-02	7.10E-02			2
Cycloalkanes		Total Dicycloalkanes	3.40E+00					1
		Total Hexacycloalkanes	4.00E-01					1
		Total Monocycloalkanes	3.90E+00					1
		Total Pentacycloalkanes	1.90E+00					1
		Total Tetracycloalkanes	2.70E+00					1
		Total Tricycloalkanes	2.90E+00					1
Metals		Nickel	8.90E-03					1
		Vanadium	7.30E-03					1
Monoaromatics	10	Total Indans and Tetralins	2.10E+00					1
n-Alkanes		Total n-alkanes n-C32 and larger	5.00E-02					1
	9	n-Nonane	3.40E-03	9.00E-04	5.90E-03			2
	10	n-Decane	8.80E-03	2.70E-03	1.50E-02			2
	11	n-Undecane	1.50E-02	5.70E-03	2.50E-02			2
	12	n-Dodecane	2.20E-02	1.00E-02	3.40E-02			2
	13	n-Tridecane	4.30E-02	1.70E-02	7.00E-02	2.70E-02	6.20E+01	3
	14	n-Tetradecane	6.30E-02	2.40E-02	1.10E-01	4.40E-02	6.90E+01	3
	15	n-Pentadecane	7.30E-02	3.00E-02	1.20E-01	4.50E-02	6.20E+01	3
	16	n-Hexadecane	9.00E-02	4.40E-02	1.40E-01	4.80E-02	5.40E+01	3
	17	n-Heptadecane	1.00E-01	5.60E-02	1.50E-01	4.70E-02	4.60E+01	3
	18	n-Octadecane	8.80E-02	4.10E-02	1.20E-01	4.20E-02	4.70E+01	3
	19	n-Nonadecane	1.00E-01	5.50E-02	1.40E-01	4.30E-02	4.30E+01	3
	20	n-Eicosane	1.00E-01	6.00E-02	1.20E-01	3.40E-02	3.40E+01	3
	21	n-Heneicosane	1.00E-01	6.40E-02	1.30E-01	3.40E-02	3.30E+01	3
	22	n-Docosane	1.00E-01	6.80E-02	1.40E-01	3.40E-02	3.30E+01	3
	23	n-Tricosane	9.60E-02	6.70E-02	1.30E-01	3.30E-02	3.40E+01	3
	24	n-Tetracosane	9.30E-02	6.70E-02	1.30E-01	3.40E-02	3.60E+01	3
	25	n-Pentacosane	8.20E-02	6.20E-02	1.10E-01	2.80E-02	3.40E+01	3
	26	n-Hexacosane	7.10E-02	5.00E-02	1.00E-01	2.90E-02	4.00E+01	3
n-Alkanes (continued)	27	n-Heptacosane	6.60E-02	4.00E-02	9.90E-02	3.00E-02	4.60E+01	3
	28	n-Octacosane	6.60E-02	5.00E-02	9.20E-02	2.30E-02	3.50E+01	3
	29	n-Nonacosane	5.80E-02	4.00E-02	8.50E-02	2.30E-02	4.00E+01	3
	30	n-Triacontane	5.30E-02	4.00E-02	7.50E-02	2.00E-02	3.70E+01	3
	31	n-Hentricontane	4.60E-02	3.70E-02	6.00E-02	1.20E-02	2.70E+01	3
	32	n-Dotriacontane	4.10E-02	3.20E-02	5.10E-02			2
	33	n-Tritriacontane	3.10E-02	2.60E-02	3.60E-02			2
	34	n-Tetratriacontane	2.60E-02	2.20E-02	3.00E-02			2
	35	n-Pentatriacontane	1.50E-02	1.50E-02	1.50E-02			2
	36	n-Hexatriacontane	1.10E-02	1.10E-02	1.10E-02			2
	37	n-Heptatriacontane	9.60E-03	9.20E-03	9.90E-03			2
	38	n-Octatriacontane	7.70E-03	6.60E-03	8.70E-03			2
	39	n-Nonatriacontane	6.20E-03	4.80E-03	7.60E-03			2
	40	n-Tetracontane	4.80E-03	4.20E-03	5.50E-03			2
Naphthalenes		Total Naphthalenes	9.80E-02	4.00E-04	9.20E-01	2.60E-01	2.70E+02	12
	10	Naphthalene	4.20E-03	2.10E-04	1.50E-02	7.00E-03	1.70E+02	4
	11	Total Methylnaphthalenes	2.60E+00					1
Other		Asphaltenes and Polars	5.80E+00	7.00E-02	2.50E+01	7.80E+00	1.30E+02	12
		Insolubles	1.40E+01					1
		Polar Materials	3.00E+01					1
	12	Total Dibenzothiophenes	9.80E-02	2.00E-04	7.00E-01	1.80E-01	1.90E+02	13
Polynuclear Aromatics		Total Chrysenes	1.80E-02	2.30E-03	2.70E-02	7.00E-03	4.00E+01	12
		Total Fluoranthenes	1.80E-02	3.00E-04	3.30E-02	1.10E-02	6.40E+01	12
		Total Phenanthrenes	6.60E-02	1.30E-03	1.50E-01	5.00E-02	7.60E+01	13
	14	Anthracene	5.00E-03					1
	14	Phenanthrene	2.10E-02	2.10E-03	4.80E-02	2.40E-02	1.20E+02	5
	15	1-Methylphenanthrene	4.30E-03					1
	15	2-Methylphenanthrene	8.30E-02					1
	16	Fluoranthene	2.40E-02					1
	16	Pyrene	2.30E-03					1
	18	Benz(a)anthracene	5.50E-02	2.90E-03	1.50E-01	8.40E-02	1.50E+02	3
Polynuclear Aromatics (continued)	18	Chrysene	6.90E-02	2.90E-03	3.10E-01	1.30E-01	2.00E+02	5
	18	Triphenylene	3.10E-03					1
	20	Benzo(a)pyrene	4.40E-03					1
	20	Benzo(b+k)fluoranthene	4.40E-02					1
	20	Benzo(e)pyrene	1.00E-03					1
	20	Perylene	2.20E-03					1
	22	Indeno(1,2,3-cd)pyrene	1.00E-02					1
Total Aromatics		Total Aromatics	3.40E+01					1
Total n-Alkanes		Total n-Alkanes	1.70E+00					1
Total Straight-Chain and Branched Alkanes		Total Straight-Chain and Branched Alkanes	1.30E+01	5.00E+00	2.10E+01			2

Source: Thomas L. Potter; Kathleen E. Simmons, "Volume 2:Composition of Petroleum Mixtures". 1998, ISBN 1-884-940-19-6

Table 4A
Composition of Used Crankcase Oil

Derivation of Cleanup Levels for GRO and DRO

ATSDR 1997
Mixture of low and high C15 - C50 aliphatic and aromatic hydrocarbons

	Volume %	Correlates to MADEP Fraction:
alphatic hydrocarbons	73-80%	>C9 aliphatics
monoaromatic hydrocarbons	11-15%	C11-C22 aromatics
diaromatic hydrocarbons	2-5%	C11-C22 aromatics
polyaromatic hydrocarbons	4-8%	C11-C22 aromatics

Mass DEP, 2008	Percent
C11-C22 Aromatics	60
C9-C18 Aliphatics	40
C19-C36 Aliphatics	0

Composition for Derivation of Cleanup Levels

Aliphatic C9-C18	72%	Based on aliphatics from ATSDR, 1997; supported by sum of alkanes (80%) from Table 4B
Aromatic C11-C22	28%	Based on sum of aromatics (sum of maximum) from ATSDR, 1997; supported by total aromatics value (22%) from Table 4B
Carcinogenic PAHs	0.042%	Based on data in Table 4B
Naphthalenes	3.20%	Based on data in Table 4B

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. Toxicological profile for used mineral-based crankcase oil. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Massachusetts Department of Environmental Protection (MassDEP), 2002. "Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MADEP EPH/VPH Approach". Final Policy #WSC-020411. October 31.

Table 4B
Summary of Composition Data for Used Crankcase Oil

Derivation of Cleanup Levels for GRO and DRO

compound class	carbon #	compound	average wt %*	minimum*	maximum*	stdev*	coefficient of variation*	total number of data points
Alkyl-Monoaromatics		Total Alkyl-Monoaromatics	4.20E+00	1.00E-01	8.40E+00			2
	6	Benzene	9.60E-02	5.90E-02	9.60E-02			237
	7	Toluene	2.20E-01	1.00E-01	2.20E-01			243
	8	Total Xylenes	3.40E-01	2.00E-01	3.40E-01			236
Branched Alkanes	10	trans-Decalin	1.00E-03					1
	19	Pristane	2.00E-02	1.20E-02	2.80E-02			2
	20	Phytane	2.70E-02	1.80E-02	3.70E-02			2
Chlorinated Solvents	1	Dichlorodifluoromethane	3.70E-02					87
	2	1,1,1-Trichloroethane	2.80E-01	4.00E-02	2.80E-01			617
	2	Tetrachloroethylene (PCE)	1.40E-01	1.80E-02	1.40E-01			600
	2	Trichloroethylene (TCE)	1.40E-01	2.50E-04	1.40E-01			609
	2	Trichlorotrifluoroethane	6.30E+00					28
Cycloalkanes		Total Dicycloalkanes	1.00E+01					1
		Total Hexacycloalkanes	1.90E+00					1
		Total Monocycloalkanes	7.00E+00					1
		Total Pentacycloalkanes	3.70E+00					1
		Total Tetracycloalkanes	5.90E+00					1
		Total Tricycloalkanes	6.60E+00					1
	15	Nonylcyclohexane	1.50E-03	9.00E-04	2.20E-03			2
	16	Octylcyclohexane	1.10E-03	1.00E-03	1.10E-03			2
Diaromatics (Except Naphthalenes)		TotalBiphenyls/Acenapthenes/Fluorenes	6.40E+00					1
		Total Fluorenes	3.40E-03					1
	12	Biphenyl	6.40E-03	4.60E-03	8.30E-03			2
	13	4-Phenyltoluene	4.00E-04	2.00E-04	6.00E-04			2
	13	Fluorene	4.50E-03	1.70E-04	1.10E-02	5.30E-03	1.20E+02	5
	13	Total Methylbiphenyls	2.30E-04					1
	14	Total Methylfluorenes	2.80E-04					1
	15	Total Dimethylfluorenes	1.40E-04					1
	16	Total Trimethylfluorenes	1.30E-04					1
Inorganics		Total Chlorine	5.00E-01	1.20E-01	5.00E-01			591
Metals		Arsenic	1.70E-03	1.00E-03	1.70E-03			538
		Barium	1.30E-02	1.30E-02	2.10E-02			753
		Cadmium	3.10E-04	1.70E-04	3.10E-04			745
		Chromium	2.80E-03	1.10E-04	2.80E-03			757
Metals (continued)		Lead	6.70E-02	6.60E-02	2.60E-01			836
		Zinc	5.80E-02	5.80E-02	9.80E-02			811
Monoaromatics	10	Tetralin	1.20E-03	7.00E-05	2.40E-03			2
	14	Total Napthenobenzenes	9.80E+00					1
n-Alkanes	12	n-Dodecane	1.40E-02					1
	13	n-Tridecane	1.30E-02	2.60E-03	2.30E-02			2
	14	n-Tetradecane	1.40E-02	1.30E-02	1.50E-02			2
	15	n-Pentadecane	1.30E-02	1.20E-02	1.40E-02			2
	16	n-Hexadecane	2.10E-02	1.40E-02	2.80E-02			2
	17	n-Heptadecane	3.70E-02	2.20E-02	5.30E-02			2
	18	n-Octadecane	5.10E-02	3.70E-02	6.40E-02			2
	19	n-Nonadecane	7.40E-02	6.70E-02	8.20E-02			2
	20	n-Eicosane	2.00E-01	1.80E-01	2.20E-01			2
Naphthalenes		Total Naphthalenes	3.20E+00	5.00E-02	6.40E+00			2
	10	Naphthalene	5.90E-02	5.00E-05	2.50E-01	1.30E-01	1.00E+02	29
	11	1-Methylnaphthalene	3.00E-03	2.00E-04	5.70E-03			2
	11	Total Methylnaphthalenes	5.20E-01	4.10E-01	6.30E-01			2
	12	1,5-Dimethylnaphthalene	2.90E-03	3.00E-04	5.60E-03			2
	12	2-Ethylnaphthalene	3.00E-03	2.00E-04	5.80E-03			2
	12	Total Dimethylnaphthalenes	3.70E-01	3.00E-01	4.50E-01			2
	13	1,3,5-Trimethylnaphthalene	2.00E-03	4.00E-04	3.70E-03			2
Other		Total Polychlorinated Biphenyls (PCB's)	1.10E-02	3.90E-03	1.10E-02			754
		Total Sulfur Containing Heterocyclics	2.30E-03					1
	12	Dibenzothiophene	9.00E-05					1
	13	Total Methyldibenzothiophenes	2.60E-04					1
	14	Total Dimethyldibenzothiophenes	4.40E-04					1
	15	Total Trimethyldibenzothiophenes	2.20E-04					1
	16	Benzo(b)naptho(2,1-d)thiophene	3.80E-04	1.90E-04	4.80E-04	8.60E-05	2.90E+01	81
	16	Benzonaphthothiophene	3.90E-05					1
	16	Other Benzonaphthothiophenes	1.40E-04					1
	16	Phenanthro(4,4a,4b,5-bcd)thiophene	4.10E-05					1
	16	Total Benzonaphthofurans	5.10E-05					1
	17	Total Methylbenzonaphthothiophenes	6.20E-05					1
Other (continued)	22	Triphenylene(4,4a,4b,5-bcd)thiophene	1.20E-05					1
Polynuclear Aromatics		Terphenyl	1.40E-05					1
		Total Benzanthracenes/Chrysenes/ Triphenylenes	3.40E-03					1
		Total Fluoranthenes	6.80E-03					1
		Total Perylenes	1.00E+00					1
		Total Phenanthrenes	3.70E+00	2.50E-02	7.40E+00			2
	14	Anthracene	2.20E-03	3.80E-05	4.70E-03	2.10E-03	9.60E+01	4
	14	Phenanthrene	7.90E-03	4.00E-04	1.90E-02	8.70E-03	1.10E+02	6
	15	Total Methylanthracenes	6.60E-05					1
	15	Total Methylphenanthrenes	4.40E-02	1.30E-03	6.70E-02	3.70E-02	8.40E+01	3
	16	Fluoranthene	3.80E-03	7.00E-05	9.10E-03	3.30E-03	1.30E+02	86
	16	Phenylnaphthalene	1.00E-04					1
	16	Pyrene	1.00E-02	1.70E-04	1.60E-02	3.70E-03	1.40E+02	86
	16	Total Dimethylanthracenes	3.00E-05					1
	16	Total Dimethylphenanthrenes	1.20E-03					1
	17	1-Methylpyrene	1.30E-04					1

Table 4B
Summary of Composition Data for Used Crankcase Oil

Derivation of Cleanup Levels for GRO and DRO

compound class	carbon #	compound	average wt %*	minimum*	maximum*	stdev*	coefficient of variation*	total number of data points
	17	4-Methylpyrene	1.90E-04					1
	17	Benzo(a)fluorene	1.90E-04	1.10E-04	2.70E-04			2
	17	Benzo(b)fluorene	1.60E-04					1
	17	Benzo(c)fluorene	5.00E-05					1
	17	TotalBenzofluorenes	3.80E-04					1
	17	Total Dihydromethylpyrenes	5.10E-05					1
	17	Total Methylpyrenes	4.80E-04					1
	17	Total Trimethylanthracenes	5.80E-05					1
	17	Total Trimethylphenanthrenes	6.90E-04					1
	18	Benz(a)anthracene	6.30E-03	3.40E-05	7.10E-03	2.20E-03	1.40E+02	32
	18	Benzo(c)phenanthrene	1.40E-05					1
	18	Chrysene	3.50E-03	1.30E-04	8.50E-03	4.00E-03	1.20E+02	4
	18	Chrysene and Triphenylene	1.40E-03	2.40E-04	3.40E-03	1.30E-03	9.00E+01	5
	18	Total Chrysenes and Benzanthracenes	2.20E+00					1
	18	Total Chrysenes and Triphenylenes	2.80E-03	2.80E-04	3.80E-03			77
	18	Total Diethylphenanthrenes	1.40E-04					1
	18	Total Dimethylpyrenes	1.90E-04					1
Polynuclear Aromatics (continued)	18	Triphenylene	2.50E-04					1
	19	Total Ethylmethylpyrenes	1.60E-05					1
	19	Total Methylbenzo(a)anthracenes	2.80E-04					1
	20	Benzo(a)pyrene	1.70E-03	3.00E-06	2.50E-03	7.10E-04	1.80E+02	151
	20	Benzo(b)fluoranthene	4.00E-05	3.70E-05	4.30E-05			2
	20	Benzo(e)pyrene	1.70E-03	2.20E-05	3.10E-03	1.30E-03	1.50E+02	84
	20	Benzo(k)fluoranthene	6.10E-05	4.00E-06	1.60E-04	8.60E-05	1.40E+02	3
	20	Ethylbenz(a)anthracene	7.40E-05					1
	20	Perylene	3.50E-04	8.00E-06	5.10E-04	2.00E-04	1.90E+02	82
	20	Total Benzofluoranthenes (b+j+k)	1.50E-03	1.20E-05	2.60E-03	1.10E-03	1.40E+02	81
	20	Total Benzpyrenes and Benzfluoranthenes	2.50E-03					1
	21	Cyclopenta(cd)pyrene	8.90E-05					1
	21	Methylbenzo(mno)fluoranthene	3.40E-05					1
	21	Total Ethylcyclopenta(def)phenanthrenes	1.60E-04					1
	21	Total Methylbenzo(e)pyrenes	2.60E-05					1
	21	Total Methylbenzofluoranthenes	2.10E-05					1
	21	Total Methylbenzopyrenes	4.70E-05					1
	22	Benzo(g,h,i)perylene	2.80E-03	7.00E-06	4.80E-03	1.70E-03	2.40E+02	84
	22	Dibenz(a,c)anthracene	8.00E-06					1
	22	Indeno(1,2,3-cd)pyrene	4.00E-03	1.10E-06	6.10E-03	3.10E-04	1.70E+02	82
	24	Coronene	7.00E-05	8.50E-07	1.70E-03	7.20E-04	1.90E+02	27
	24	Total Benzper ylenes	2.70E-03					1
Total Aromatics		Total Aromatics	2.20E+01	2.00E-01	4.50E+01	2.20E+01	1.00E+02	3
Total Cycloalkanes		Total Cycloalkanes	2.90E+01					1
Total Straight-Chain and Branched Alkanes		Total Straight-Chain and Branched Alkanes	4.40E+01	1.70E+01	6.10E+01	2.30E+01	5.30E+01	3

Source: Thomas L. Potter; Kathleen E. Simmons, "Volume 2:Composition of Petroleum Mixtures". 1998, ISBN 1-884-940-19-6

Table 5A
Stoddard Solvent

Derivation of Cleanup Levels for GRO and DRO

Air Force, 1989	Percent Composition	Correlates to MADEP Fraction:
Linear and branched alkanes	30% - 50%	C9-C18 aliphatic
Cycloalkanes	30% - 40%	C9-C18 aliphatic
Aromatics	10% - 20%	C9-C10 aromatic
Benzene	trace	
Olefins	trace	

Mixture of C7 - C11 with predominantly C9 to C11.
140 flash solvent C5 to C12

Composition for Derivation of Cleanup Levels

Aliphatic C5-C8	20%	Based on Air Force, 1989. Assumes 80% alkanes; 20% of which are in the C5-C8 range
Aliphatic C9-C18	60%	Based on Air Force, 1989. Assumes 80% alkanes; 60% of which are in the C9-C18 range
Aromatic C9-C10	20%	Based on Air Force, 1989.