

**ALASKA DEPARTMENT OF
ENVIRONMENTAL CONSERVATION**

**DIVISION OF SPILL PREVENTION AND RESPONSE
CONTAMINATED SITES PROGRAM**



**CLEANUP LEVELS GUIDANCE
FOR METHODS TWO AND THREE**

****DRAFT****

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METHOD THREE CLEANUP LEVEL GUIDANCE

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1.0 Introduction

State of Alaska Regulations at 18 AAC 75, Article 3, for Oil and Other Hazardous Substances Pollution Control, govern the cleanup of sites contaminated with oil or other hazardous substances. Sections of this regulation address the selection or development of cleanup levels for contaminated soil and groundwater that are considered protective of human health, safety, and welfare, and the environment. Cleanup levels at a site may be determined by one or more of four methods. Section 18 AAC 75.340 of the regulations addresses the selection or development of cleanup levels for contaminated soil that are considered protective of human health, safety, and welfare, and the environment, using one of these four methods.

Method one cleanup levels listed in 18 AAC 75.341(a) and (b) apply only to soil contaminated with petroleum hydrocarbons and are not considered risk-based. Method two cleanup levels for approximately 180 chemicals are listed in 18 AAC 75.341(c) and for petroleum hydrocarbons in 18 AAC 75.341(d). These levels are generally risk-based, incorporating toxicity and chemical specific information, assessing multiple routes of exposure in climate settings that reflect the variability found across the state, and the potential for a given chemical to migrate from soil to groundwater. However, if the risk-based cleanup level exceeds the soil saturation or water solubility limit, the cleanup level is set at that limit in compliance with 18 AAC 75.325(f), which requires free product recovery. Though still somewhat generic, the method two levels are considered protective of human exposure for most sites. Determining cleanup levels under method three allows for modification of the default method two soil cleanup levels to account for site-specific soil and aquifer data or to propose a commercial/industrial indoor or outdoor exposure scenario. Other land use scenarios, such as recreation or subsistence land use, should be addressed under method four. Method four cleanup levels are developed under a risk assessment conducted in accordance with the department's *Risk Assessment Procedures Manual* (ADEC, 2015).

This document provides background on the development of the method two cleanup levels and guidance on how to develop alternative cleanup levels under method three. The process for obtaining department approval of a soil cleanup level under method two and three is outlined, and the process for proposing an alternative cleanup level under method three using the department's standard equations is described. A discussion of the soil and human health exposure parameters is provided. All equations mentioned in this document are utilized by the department's online Cleanup Levels Calculator available at:

<http://dec.alaska.gov/spar/csp/Calculators.htm>, with the exception of the equations used to calculate petroleum cleanup levels. These are utilized by the online Petroleum Cleanup Levels Calculator found at: <http://dec.alaska.gov/spar/csp/Calculators.htm>.

Note: Method Three does not apply to groundwater. Alternative groundwater cleanup levels may only be proposed under a Method 4 risk assessment under 18 AAC 345(b)(2).

Method three allows for modification of the default soil cleanup levels to account for site-specific soil and aquifer data as well as a commercial/industrial land use scenario. Method three also allows for a Responsible Party (RP) to propose an alternative cleanup level for soil that eliminates one or more human health exposure routes if they are not present at a site, subject to institutional controls (ICs) that may apply. Although not addressed in this guidance, an RP may also propose alternative cleanup levels for migration to groundwater under method three using an approved fate and transport model and site-specific data that comply at a minimum with the recommendations set

forth in this guidance for each specific parameter. For more on fate and transport models, see DEC's *Fate and Transport Modeling Guidance*, January 2017b.

This document is not intended to provide guidance on other applicable requirements in developing soil cleanup levels under 18 AAC 75.340, such as the regulatory requirements for selecting the applicable groundwater cleanup levels and public and landowner participation or consultation. It is also not intended to address the regulatory requirements for cumulative risk determinations or ICs.

Terms used in this guidance have the meaning given in 18 AAC 75.990.

2.0 Method Two Soil Cleanup Levels Development

Four sets of soil cleanup levels are established in Table B1 of 18 AAC 75.341, three of which are based on climate variations throughout the state and are designed to be protective of human health exposures through ingestion, inhalation, and dermal contact. The fourth set of cleanup levels, for the migration to groundwater pathway, are set at concentrations intended to prevent migration to groundwater at levels that would exceed the groundwater criteria in Table C. Note that for the petroleum cleanup levels in Table B2, separate migration to groundwater cleanup levels are presented for each of the under 40 inch and over 40 inch zones. For more on the climate zones, see Section 8.0.

The department developed the default soil cleanup levels based on the approach used to develop EPA's Regional Screening Levels (RSLs), but adapted it for Alaska using certain Alaska specific values for some of the input parameters, and referencing the methodology presented in the Environmental Protection Agency's (EPA's) *Soil Screening Guidance: User's Guide*, (EPA, 1996a) for others. A discussion of the exposure parameters and the soil and aquifer parameters that can be modified under method three is provided in Section 6.0. These equations and default parameters were used to calculate numerical soil cleanup levels that are protective of human health, based on exposure to a hazardous substance and the toxicity of a hazardous substance for specified exposure pathways. These equations and the default input parameters are listed in the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) and can also be found in the online Cleanup Levels Calculator, available at: <http://dec.alaska.gov/spar/csp/Calculators.htm>. A discussion of the equations is presented in Section 8.0.

Soil cleanup levels under method two are generic and generally risk-based cleanup levels for the hazardous substances listed in Table B1 and B2. The only land use scenario that applies under method two is a residential land use scenario, where an individual is assumed to reside at a site for 26 years. A commercial/industrial land use scenario for outdoor or indoor worker can be addressed under method three.

2.1 Table B1 Cleanup Levels

Cleanup levels listed in Table B1 are considered protective of human health for the following exposure pathways combined under a residential land use scenario:

- ingestion;
- inhalation of volatile compounds and particulates of non-volatile compounds; and
- dermal contact
- the migration of hazardous substances from the soil to underlying groundwater, where the groundwater is considered a current or potential drinking water source.

The cleanup levels are protective of both children and adults; however other sensitive subpopulations may need to be evaluated separately. Typically, young children are more sensitive. For example, they ingest more soil than older children or adults; therefore, the calculations for exposure through ingestion were developed to be protective of this higher rate of ingestion during early childhood.

2.2 Table B2 Petroleum Cleanup Levels

Cleanup levels for the petroleum ranges in Table B2 are considered protective of human health for the following exposure pathways under a residential land use scenario:

- ingestion
- inhalation
- the migration of hazardous substances from the soil to underlying groundwater, where the groundwater is considered a current or potential drinking water source.

Table B2 lists separate cleanup levels for ingestion and inhalation in each climate zone rather than a combined value as shown in Table B1.

3.0 Process for Determining Method Two Cleanup Levels

3.1 Conceptual Site Model

The default cleanup levels that apply at a site under method two must be determined before proposing an alternative cleanup level under method three. Therefore the complete exposure pathways at a site is best identified by developing a conceptual site model. A conceptual site model is a visual flowchart or illustration that is helpful to show the contaminant sources, exposure routes and migration pathways that can lead to complete or potentially complete exposures to both human health and ecological receptors as well as impacts to environmental media. The conceptual site model may also identify other exposure pathways present at the site, such as inhalation of indoor air contaminated with volatile hazardous substances, the presence of sensitive sub-populations, and ecological receptors. Any of these or other exposures present at a site will influence alternative cleanup levels and may require further evaluation.

A conceptual site model, along with supporting documentation (such as site history, list of chemicals used at a site, site activities and land use designations) should be included in all site characterization work plans and reports submitted to the department for approval. A conceptual site model is a flow chart or diagram that identifies each current or potential future complete exposure pathway for each contaminant at a site. In general, a complete exposure pathway consists of a source of contamination, its route of transport to environmental media, and the route of exposure from that media to a receptor. For complete instructions on how to develop a conceptual site model, consult the department's *Guidance on Developing Conceptual Site Models* (ADEC, 2017a).

If a responsible party demonstrates that there are no ecological receptors at a site, or that method two cleanup levels are determined protective of the ecological receptors present, then method two can be used to select applicable soil cleanup levels. The migration to groundwater pathway applies to a site under method two unless a responsible person demonstrates and the department determines that there is no groundwater present at the site or that groundwater is not a current or likely potential future drinking water source.

3.2 Cleanup Level Selection Process

The following steps describe the process for selecting a method two soil cleanup level for a site. Final approval of the soil cleanup level for each hazardous substance is made by the department and documented in the approval letter for the site characterization report, the cleanup plan or in the record of decision during in the cleanup process.

1. In consultation with the department, establish the climate zone where the site is located.
2. Under the applicable climate zone, select the most stringent of the pathway-specific cleanup levels listed for each hazardous substance in Table B1, and each petroleum hydrocarbon range in Table B2, if present at a site. In order to rule out the migration to groundwater pathway, provide detailed information to the department demonstrating that groundwater is not present at the site or how the soil to groundwater pathway is otherwise incomplete. For example, for a site in the arctic zone, documentation must be provided to show that a continuous permafrost layer is present and acting as a barrier for migration of contaminants from soil to a groundwater zone of saturation. In addition, if suprapermafrost groundwater is present, it must also be evaluated as a mechanism for contaminant transport to surrounding soil, groundwater, and surface water.¹ For a site where groundwater is present but is not considered a current or potential future drinking water source, a responsible party must demonstrate that the criteria in 18 AAC 75.350 have been met.
3. Present the selected cleanup levels, conceptual site model, and supporting documentation along with a preliminary cumulative risk determination in the site characterization report. If multiple contaminants are present at a site or if a hazardous substance is present in multiple pathways, a cumulative risk evaluation is strongly encouraged at this stage in order to ensure that the risk from exposure to multiple contaminants at the site's proposed cleanup levels does not exceed acceptable risk standards of 1×10^{-5} and a hazard index of 1. Additional discussion of cumulative risk is provided in the department's *Procedures for Calculating Cumulative Risk* (ADEC, 2016b), which can be calculated for Table B1 and Table C compounds using the department's online Cumulative Risk Calculator, available at: <http://dec.alaska.gov/spar/csp/Calculators.htm>.
4. Following a review of the cleanup levels, cumulative risk evaluation and any additional documentation in the site characterization report, the department will determine whether the proposed cleanup levels are approved.
5. Soil cleanup levels under method two may not be appropriate if unique receptors or activities are present at the site, if contaminants are present that are not listed in Table B1 or B2, or if site soil and groundwater conditions vary significantly from the assumptions used to calculate the

¹ See "Establishing Arctic Zone Cleanup Levels" Technical Memorandum, March 2017.

method two cleanup levels. In such instances, a responsible party should consult with the assigned project manager for the site on how to proceed under method three or method four.

4.0 Method Three Soil Cleanup Levels

Method three was developed to provide flexibility by allowing site-specific alternative cleanup levels for soil. This method allows for the use of site soil data, aquifer data, or both, and it also allows for the use of commercial/industrial exposure values without performing a full risk assessment under method four.

Under 18 AAC 75.340 there are three options for determining alternative cleanup levels for soil under method three.

1. The migration to groundwater and the human health cleanup levels for Table B1 compounds or the inhalation levels for Table B2 compounds can be modified using site-specific soil data and the equations set out in the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a).
2. The migration to groundwater cleanup level may also be modified using site specific data and a fate and transport model that meets the approval of the department.
3. The human health cleanup level may be modified using the commercial/industrial (outdoor or indoor worker) exposure parameters listed in Table 3 below and the equations listed in the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a). The use of other values for exposure parameters for either a commercial/industrial site or to address other land uses, such as recreational or subsistence use, may only be proposed under method 4.

If the default soil or aquifer parameter values are found not to be sufficiently protective at a particular site, such as an organic carbon content that is less than the default, or lower hydraulic conductivity, the Department may require or may set an alternative cleanup level under method three using site-specific data.

5.0 Process for Developing Method Three Cleanup Levels

5.1 Conceptual Site Model

The requirements for developing and submitting a conceptual site model under method three are the same as for method two. See the department's *Guidance for Developing a Conceptual Site Model* (ADEC, 2017a).

5.2 Steps for Proposing a Site-Specific Cleanup Level

The following steps describe the process for developing a proposed method three soil cleanup level for a hazardous substance at a site, and requires communication with the department throughout the process. Scoping the required data for calculating a method three alternative cleanup level should be conducted as early as possible in the characterization and cleanup process. Final approval of the soil cleanup level for each hazardous substance is in most cases made by the department in the site characterization report approval or, for Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) sites, during the record of decision step in the cleanup process.

For non-CERCLA sites, you must prepare a site characterization report. In this report, provide detailed documentation and discussion of the following to the department:

1. The applicable groundwater cleanup level and any associated ICs required to protect human health. If groundwater at the site is not considered a current or reasonably expected potential future drinking water source, the responsible party must demonstrate or the department may determine that the criteria for this designation are met under 18 AAC 75.350, and that the groundwater impacted by the hazardous substance will not be transported to groundwater that is a source of drinking water now or in the future. State the criteria met and proceed to step 2.
2. Residential land use is assumed; however, if commercial/industrial land use applies, describe the current zoning, the nature of the current and expected future use of the land, and the associated IC(s) required to insure that land use scenario.
3. The climate zone where the site is located.
4. All site-specific soil and aquifer parameters, and the sources and methods by which they were collected or generated. Include a tabulated summary of parameters using a format similar to Table 4.
5. How the alternative cleanup levels were calculated. Approval for a fate and transport model per 18 AAC 75.340(e)(2) for calculating an alternative migration to groundwater cleanup level should be obtained prior to report submission. The specific criteria that models must meet in order to be approved by the department can be obtained from the contaminated site project manager and the ADEC *Fate and Transport Modeling Guidance* (2017b).

6. All modeling inputs and results. This includes the input parameter summary tables generated by the Cleanup Levels Calculator and the Petroleum Cleanup Levels Calculator.
7. A table of the cleanup levels for each hazardous substance for each complete exposure pathway. This may include a mix of default method two cleanup levels and alternative cleanup levels calculated under method three. Specify what method was used to determine the cleanup level for each hazardous substance and each pathway, and highlight the most stringent applicable cleanup level for each contaminant.

The most stringent of the applicable pathway-specific cleanup levels applies at a site. For example, method three may be used to develop an alternative cleanup level for the migration to groundwater pathway. However, if the alternative cleanup level exceeds the default method two human health cleanup level for that hazardous substance, the human health cleanup level would apply for that hazardous substance. Furthermore, alternative cleanup levels for Table B2 compounds may not exceed the Maximum Allowable Concentrations listed in Table B2, unless, as described in footnote 17 to the table, a responsible person demonstrates that the petroleum hydrocarbon will not migrate and will not pose a significant risk to human health, safety, or welfare, or to the environment; free product must be recovered as required by 18 AAC 75.325(f).

5.3 Cumulative Risk Calculations under Method 3

If multiple contaminants are present at a site or if a hazardous substance is present in multiple pathways, a cumulative risk determination is required in order to ensure that the risk from exposure to multiple contaminants does not exceed acceptable risk management levels. Additional discussion of cumulative risk is provided in the department's *Procedures for Calculating Cumulative Risk* (ADEC, 2016b). Cumulative risk may be calculated using the department's online Cumulative Risk Calculator, available at: <http://dec.alaska.gov/spar/csp/Calculators.htm>. Alternative cleanup levels may be approved at a site even though they are expected to exceed cumulative risk standards. If the site is slated for closure, an IC must be established documenting measures that will be taken to prevent exposure to contaminants that would otherwise pose risk above the department's cumulative risk standard; otherwise the site must remain open until cumulative risk is reduced below the standard.

6.0 Specific Alternative Cleanup Levels under Method Three

This section provides instructions on calculating a variety of site-specific cleanup levels under the three broad options listed above, including how to use extractable and volatile petroleum hydrocarbon (EPH and VPH) analytical data for site-specific petroleum cleanup levels, calculating site-specific saturation levels, and developing cleanup levels for contaminants not listed in regulation.

6.1 Method Three Cleanup Levels for the Migration to Groundwater Pathway

The following sections describe the parameters that may be modified using site data for contaminants in Table B1 and petroleum ranges in Table B2. Certain conditions apply to modifying the parameters. For example, if a site-specific dry soil bulk density will be used, then the total porosity, air-filled porosity and water-filled porosity must be calculated using the appropriate equation.

Under method three, details for the conceptual site model which may affect the default assumptions in the equations must be evaluated carefully— including those outlined at the end of section 8.5 of this document. For developing alternative migration to groundwater cleanup levels, particular attention should be paid to where the contaminant mass is located in the soil: the vadose zone, the variably saturated zone, or the permanently saturated zone. This greatly affects the model presumption that the receptor well is located at the downgradient edge of the source area and screened within the plume, and model results may need to be reevaluated based on this information.

6.1.1 Table B1 Contaminants

Alternative residential soil cleanup levels may be developed under method three (18 AAC 75.340(e)) utilizing site-specific data for the migration to groundwater pathway. Site-specific parameters that may be modified for Table B1 compounds are listed in [Table 1](#). Migration to groundwater equations for the Table B1 contaminants and the sources for the default values for the parameters are found in Section 4.0 of *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) and in the online Cleanup Levels Calculator at <http://dec.alaska.gov/spar/csp/Calculators.htm>.

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

If a site-specific dry soil bulk density will be used, then the total porosity, air-filled porosity, and water-filled porosity must be calculated using the appropriate equation the respective contaminant.

A standard default mixing zone depth of 5.5 meters has been adopted by the department for application to Table B1 contaminants. This value cannot be modified unless a fate and transport model approved by the department is used per 18 AAC 75.340(e)(2) (See Section 6.2).

6.1.2 Table B2 Petroleum Fractions

For petroleum fractions, alternative residential soil cleanup levels may be developed under method three (18 AAC 75.340(e)(1)) utilizing site-specific data for the soil migration to groundwater or inhalation pathway. Site-specific parameters that may be modified for Table B2 petroleum fractions are listed in Table 2. Equations for the petroleum fractions are in Section 6.0 of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) and are incorporated into the online Petroleum Cleanup Levels Calculator available at: <http://dec.alaska.gov/spar/csp/Calculators.htm>. However, alternative cleanup levels for Table B2 compounds may not exceed the Maximum Allowable Concentrations listed in Table B2, unless, as described in footnote 17 to the table, a responsible person demonstrates that the petroleum hydrocarbon will not migrate and will not pose a significant risk to human health, safety, or welfare, or to the environment; free product must be recovered as required by 18 AAC 75.325(f).

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

If a site-specific dry soil bulk density will be used, then the total porosity, air-filled porosity, and water-filled porosity must be calculated using the appropriate equation the respective contaminant.

For Table B2 petroleum fractions, the standard default mixing zone depth value can be modified using site-specific information (see Table 2 above).

6.2 Use of Site Data and an Approved Fate and Transport Model

A fate and transport model approved by the department may be used with site-specific data to calculate an alternative soil cleanup level for the migration to groundwater pathway for contaminants listed in either Table B1 or B2, as described in 18 AAC 75.340(e)(2). Modeling with site-specific data may improve the prediction of what concentration of a hazardous substance in soil will cause an exceedance of the groundwater cleanup level in a well placed at the downgradient edge of the source. For example, a model may be used to estimate the effects of a separation distance between the source in the soil column and the groundwater table or to take into account degradation of a

contaminant. Guidance on choosing a model that will meet the department’s approval is available in the department’s *Fate and Transport Modeling Guidance* (ADEC, 2017b). The guidance also provides information on the submittals the department requires. Models may require site-specific input parameters that are different than those listed in Tables 1 and 2 above. The Department will allow the use of other site specific parameters if required by an approved model. All parameters proposed for use must be submitted for department approval, including the methods for how the site data for the parameters will be collected.

6.3 Using EPH/VPH fraction data to calculate site-specific concentrations of hydrocarbons

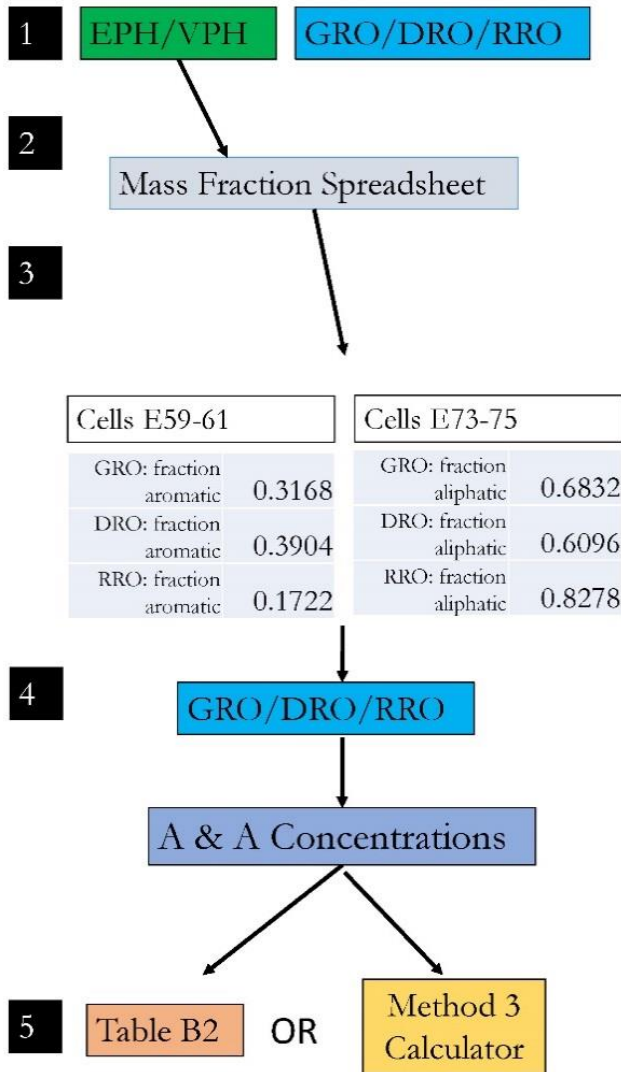
Cleanup levels for petroleum hydrocarbons are set out in Table B2 of 18 AAC 75.341(d), for gasoline range organics (GRO), diesel range organics (DRO), and residual range organics (RRO)) and separate cleanup levels “For Laboratory Analysis using AK Aliphatics and Aromatic Fraction Methods 101AA, 102AA, and 103AA.” Although the laboratory methods 101AA, 102AA, and 103AA are no longer approved, the department has approved a method to develop site-specific concentrations for comparison to the aliphatic and aromatic fractions (A&A fractions) section of Table B2 or to alternative A&A fraction cleanup levels developed using the methods outlined in 18 AAC 75.340(e). This method is described below.

The table includes cleanup levels “For Laboratory Analysis using AK Methods 101, 102, and 103.”

TABLE B2. METHOD TWO - PETROLEUM HYDROCARBON SOIL CLEANUP LEVELS										
Petroleum Hydrocarbon Range	Arctic Zone ¹ mg/kg			Under 40 Inch Zone ²			Over 40 Inch Zone ³			Maximum Allowable Concentrations ¹³ mg/kg
	Ingestion (mg/kg) ¹⁶	Inhalation (mg/kg) ¹⁷	Migration to Groundwater (mg/kg) ⁷	Ingestion (mg/kg) ¹⁸	Inhalation (mg/kg) ¹⁷	Migration to groundwater (mg/kg) ⁷	Ingestion (mg/kg) ¹⁵	Inhalation (mg/kg) ¹⁷	Migration to Groundwater (mg/kg) ⁷	
For Laboratory Analysis using AK Methods 101, 102, and 103										
C ₆ -C ₁₀ GRO using AK 101	1400	1400	n/a	1400	1400	300	1400	1400	260	1400
C ₁₀ -C ₂₅ DRO using AK 102	12500	12500	n/a	10250	12500	250	8250	12500	230	12500
C ₂₅ -C ₃₆ RRO using AK 103	13700	22000	n/a	10000	22000	11000	8300	22000	9700	22000
For Laboratory Analysis using AK Aliphatic and Aromatic Fraction Methods 101AA, 102AA, and 103AA										
C ₆ -C ₁₀ Aliphatics	1000	1000	n/a	1000	1000	270	1000	1000	240	1000
C ₆ -C ₁₀ Aromatics	1000	1000	n/a	1000	1000	150	1000	1000	130	1000
C ₁₀ -C ₂₅ Aliphatics	10000	10000	n/a	10000	10000	7200	8300	10000	6400	10000
C ₁₀ -C ₂₅ Aromatics	5000	5000	n/a	4100	5000	100	3300	5000	90	5000
C ₂₅ -C ₃₆ Aliphatics	20000	20000	n/a	20000	20000	20000	20000	20000	20000	20000
C ₂₅ -C ₃₆ Aromatics	4100	10000	n/a	3000	10000	3300	2500	10000	2900	10000

See notes to table for further requirements. “n/a” means not applicable.

6.3.1 Outline of methods



1. Characterize the site:
 - a. Develop Exposure Point Concentrations (EPCs) for GRO/DRO/RRO*
 - b. Collect EPH/VPH
2. Enter EPH/VPH results in the Mass Fraction Spreadsheet (MFS)
3. Use MFS to average EPH/VPH results and split GRO/DRO/RRO by proportion of Aromatics & Aliphatics (A&A) – Refer to MFS Cells E59-61 and E73-75
-
4. Calculate A&A concentrations by applying Mass Fraction Spreadsheet Cells E59-61 and E73-75 to GRO/DRO/RRO EPCs
-
-
-
-
5. Compare A&A concentrations to Table B2 or alternative cleanup levels developed by the Petroleum Cleanup Levels Method 3

Example: C10-25 Aromatics = [DRO EPC] * 0.3904
 C10-25 Aliphatics = [DRO EPC] * 0.6096

*Guidance on determining the exposure point concentration is explained in Section 3.2.3 of the ADEC Risk Assessment Procedures Manual

6.3.2 Site-specific data requirements

In order to use the site-specific A&A fraction approach, responsible parties are required to submit a site characterization work plan for department review and approval (the same as is required when using the online cleanup level calculator for method 3 or a method four approach). The work plan describes how each non-aqueous phase liquid (NAPL) source area will be characterized, and any data manipulation (such as statistical calculations). This calculation requires a single contaminant concentration (i.e., exposure point concentration) in soil be input to represent each mass fraction (i.e. GRO/DRO/RRO) within the NAPL source area. The work plan should describe how the input concentrations will be selected. Risks associated with contaminated soil may be evaluated

either by using the maximum measured concentration of each contaminant in the NAPL source area or an approved 95% UCL (upper confidence limit) of the mean for each contaminant.

The statistical 95% UCL may be calculated by using EPA's ProUCL software. The number of samples required to calculate the 95% UCL must be sufficient to produce a result that is representative of contamination present at the site. The department recommends a minimum of 10 data points be used to calculate the 95 UCL. However, responsible parties should bear in mind that even 10 data points may not yield a stable UCL if there is higher than normal heterogeneity in contaminant levels.

The responsible party (RP) must provide supporting documentation for the ProUCL input values. When using ProUCL, electronic copies of the input and output data from ProUCL shall be submitted to the department as part of the site characterization report. Sites with large source areas that exhibit significant variability in contaminant levels and/or heterogeneous soil properties across soil horizons may require additional data and/or separate evaluation. These site specific requirements should be part of the approved work plan.

6.3.3 Required analytical methods for petroleum fraction data

Petroleum concentrations in the NAPL source area must be characterized in two ways. Total petroleum concentrations must be analyzed using the AK series methods (AK 101, 102, and 103 for GRO, DRO, and RRO, respectively). The character of the GRO, DRO, and RRO is assessed by subdividing the GRO, DRO and RRO into smaller aromatic and aliphatic equivalent carbon groups (for example C8-C10 aromatics and C8-C10 aliphatics; C10-C12 aromatics and C10-C12 aliphatics, etc.) using EPH (for extractable aromatic and aliphatic petroleum hydrocarbons) and VPH (for volatile aromatic and aliphatic petroleum hydrocarbons) methods. The analytical procedures to be followed for these methods are those developed by the State of Washington Department of Ecology (*Analytical Methods for Petroleum Hydrocarbons*, June 1997). Documentation of the method specific (EPH and VPH) lab approval from either National Environmental Laboratory Approval Program (NELAP) or Department of Defense Environmental Laboratory Approval Program (DoD-ELAP) is required. Method-specified quality control (QC) criteria must be met for the EPH and VPH data that are used in the aliphatic and aromatic equivalent carbon characterization of GRO, DRO and RRO.

6.3.4 Converting EPH/VPH results to mass fractions

The EPH and VPH concentration results must be converted to mass fractions prior to being applied to GRO/DRO/RRO concentrations to calculate aliphatic and aromatic (A&A) fraction concentrations. A spreadsheet is available on the web page for the ADEC Petroleum Cleanup Levels Calculator here: <http://dec.alaska.gov/applications/spar/webcalc/index.htm>. The conversion procedure is described below.

To use the spreadsheet, open the file and enter the EPH and VPH concentration data from the more heavily contaminated portions of the source area into Tables 6A and 6B [Note that the table numbers shown in the spreadsheet are examples only and must be changed by the user]. The spreadsheet performs the following procedure to convert EPH and VPH data into the mass fractions. An example follows to illustrate this procedure.

1. The spreadsheet calculates the average concentration value within each fraction (e.g., C8 – C10 aromatics). The spreadsheet, by default, assigns a numerical value equal to the method detection limit to all non-detect concentration data when calculating these average values.
 -
2. The spreadsheet pulls the average concentrations in the aromatic and aliphatic equivalent carbon groups from the VPH and EPH tests into a summary table (Table 6C). For carbon fractions measured by both the VPH and EPH methods, the spreadsheet by default selects the higher of the two average concentrations. If the user has reason to believe that lower of the overlapping ranges is a more representative value, the lower value may be entered by changing the cell references as appropriate and then describing the rationale for doing so in the report narrative.
 -
3. The spreadsheet adds the concentrations within each aromatic and aliphatic equivalent carbon group to calculate a total average hydrocarbon concentration.
 -
4. The spreadsheet calculates the mass fraction within each aromatic and aliphatic equivalent carbon group by dividing the average concentration within the group by the total concentration. Results are presented in the row labeled, “Fraction of TPH mass in A&A EC groups”.
 -
5. The spreadsheet calculates the mass fraction of each aromatic and aliphatic equivalent carbon group within the larger GRO aliphatic, DRO aromatic and DRO aliphatic groups by dividing the mass fraction of each aromatic and aliphatic equivalent carbon group by the sum of the mass fractions within the larger group (e.g., the fraction of C10–C12 aliphatics within the DRO aliphatic group = C10-C12 aliphatic mass fraction / (C10-C12 aliphatic mass fraction + C12–C16 aliphatic mass fraction + C16–C21 aliphatic mass fraction)). These values are shown in Table 6D.
 -
6. The spreadsheet calculates the aromatic fraction of GRO, DRO and RRO as the sum of the GRO aromatic mass fractions divided by the sum of the GRO aromatic and aliphatic fractions. The aliphatic fractions are also calculated.

Example
Steps 1-3 are visualized below using hypothetical data.

Step 1: Average concentration of each carbon fraction (from EPH/VPH data)		
Analytical Method	Carbon Fraction	Average (mg/kg)
EPH	AR: 8-10	2.60
EPH	AR: 10-12	58.10
EPH	AR: 12-16	318.20
EPH	AR: 16-21	514.10
EPH	AR: 21-34	109.50
EPH	AL: 8-10	38.50
EPH	AL: 10-12	282.50
EPH	AL: 12-16	936.30
EPH	AL: 16-21	551.40
EPH	AL: 21-34	85.10
VPH	AR: 8-10	93.60
VPH	AR: 10-12	266.80
VPH	AR: 12-13	220.60
VPH	AL: 5-6	5.50
VPH	AL: 6-8	29.50
VPH	AL: 10-12	31.90
VPH	AL: 10-12	64.60



Step 2: Higher average concentration for each carbon fraction	
Carbon Fraction	Average (mg/kg)
AR: 8-10	93.60
AR: 10-12	266.80
AR: 12-16	318.20
AR: 16-21	514.10
AR: 21-34	109.50
AL: 5-6	5.50
AL: 6-8	29.50
AL: 8-10	38.50
AL: 10-12	282.50
AL: 12-16	936.30
AL: 16-21	551.40
AL: 21-34	85.10



Step 3: Average concentration for each group	
Group	Average (mg/kg)
GRO Aromatics (C8-C10)	93.6
DRO Aromatics (C10-21)	1099.1
RRO Aromatics (C21-C34)	109.5
GRO Aliphatics (C5-C10)	73.50
DRO Aliphatics (C10-C21)	1770.2
RRO Aliphatics (C21-C34)	85.1

The next step is calculation of the fraction aromatic of GRO, DRO and RRO using the values in Step 3. To calculate the fraction aromatic of RRO, divide the average concentration of RRO aromatics by the sum of the average concentrations of RRO aromatics and RRO aliphatics, as follows:

The A&A fractions by group are summarized in cells E59-61 and E73-75.

Aromatic Fractions - Cells E59-61	
GRO: fraction aromatic	0.56
DRO: fraction aromatic	0.383
RRO: fraction aromatic	0.563

Aliphatic Fractions - Cells E73-75	
GRO: fraction aliphatic	0.44
DRO: fraction aliphatic	0.617
RRO: fraction aliphatic	0.437

6.3.5 Application of A&A fractions

The A&A fractions by group, summarized in cells E59-61 and E73-75 of the EPH/VPH spreadsheet, may be applied to the AK101/102/103 method results for GRO/DRO/RRO to determine the site concentrations of aromatics and aliphatics for each range of hydrocarbons. Using the example data from the previous section, if a site had a DRO EPC of 10,000 mg/kg, we would use the DRO A&A fractions of 0.383 and 0.617 to calculate that we have 3,830 mg/kg C10-C25

DRO aromatics, and 6,170 mg/kg C10-C25 DRO aliphatics. The example calculations are shown below:

Example: C10-25 Aromatics = [DRO EPC] * [DRO: fraction aromatic]
 3,830 mg/kg C10-25 Aromatics = 10,000 mg/kg * 0.383

C10-25 Aliphatics = [DRO EPC] * [DRO: fraction aliphatic]
 6,170 mg/kg C10-25 Aliphatics = 10,000 mg/kg * 0.617

$$\frac{\frac{109.5 \text{ mg RRO aromatics}}{1 \text{ kg sample}} + \frac{85.1 \text{ mg RRO aliphatics}}{1 \text{ kg sample}}}{109.5 \text{ mg RRO aromatics} + 85.1 \text{ mg RRO aliphatics}} = 0.563 \frac{\text{mg RRO aromatics}}{\text{mg RRO}}$$

Once aliphatic and aromatic concentrations have been calculated, they can be compared to the bottom half of Table B2, or to alternative cleanup levels using site-specific information calculated with the Petroleum Cleanup Level Calculator (located at <http://dec.alaska.gov/applications/spar/webcalc/index.htm>).

6.4 Method Three Cleanup Levels for Human Health Exposure Routes

The following sections present how alternative cleanup levels can be calculated for a commercial/industrial exposure scenario, or by using site specific soil data to modify a cleanup level for human health or a specific exposure route (ingestion, inhalation, dermal contact). Human Health Equations for the Table B1 contaminants are found in Section 3.0 of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) and in the online Cleanup Levels Calculator accessible at <http://dec.alaska.gov/spar/csp/Calculators.htm>.

6.5 Commercial/Industrial Land Use Scenario

Alternative soil cleanup levels may be proposed for commercial/industrial exposure scenarios under method three. However, sites where a commercial/industrial exposure scenario is proposed require an IC to ensure that the land use remains commercial industrial in perpetuity, unless a future cleanup action is performed that brings the site into compliance with a residential exposure scenario. Land use is determined by the department, based upon the requirements of 18 AAC 75.340(e)(3). Values for parameters that are applied for this scenario are shown in Table 3.

Parameters	Definition (units)	Value
AT	averaging time for carcinogens (years)	70 (unchanged from residential)
AT	averaging time for non-carcinogens (days)	25 years (9125 days)
BW	body weight (kg)	80
ED	exposure duration (years)	25
EF	exposure frequency (days/years)	250 (under 40 inch and over 40 inch zones) 200 (arctic zone)
IRsoil	soil ingestion rate (mg/day)	100 (outdoor worker) 50 (indoor worker)
SA	Surface Area	3527 cm ²
AF	Adherence Factors	0.12 mg/cm ²

The inhalation cleanup levels also may be modified to account for reduced exposures in a commercial/industrial land use scenario. See Section 6.6.

For additional guidance on the equations for and calculation of commercial/industrial cleanup levels, see the EPA Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (U.S. EPA. 2002) and ADEC *Procedures for Calculating Cleanup Levels* (ADEC, 2016a).

6.6 Modification of the Inhalation Exposure Route

The inhalation pathway may be modified to take into account site soil data for the soil parameters used to calculate a volatilization factor (VF). See Section 5.1 of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) and the online Cleanup Levels Calculator, at <http://dec.alaska.gov/spar/csp/Calculators.htm>. Once a site-specific VF is calculated, it can be substituted in the carcinogenic, non-carcinogenic, and mutagenic equations used for volatile hazardous substances to generate an alternative cleanup level. Note that the calculator will automatically generate cleanup levels for each exposure route and for the saturation concentration, with the most stringent value displayed to the far right on the calculator results page. Under the regulations, the most stringent value will apply unless one or more other pathways (including migration to groundwater) are demonstrated to be incomplete at the site.

6.7 Modification of the Ingestion and Dermal Cleanup Levels

Equations in Section 3.0 (hazardous substances) and Section 6.0 (petroleum) of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) are used to calculate cleanup levels for the ingestion and dermal contact routes for hazardous substances and petroleum based on residential exposure parameters protective of childhood exposure. The only option for determining an alternative cleanup level for either of these pathways is for commercial/industrial sites where the Department has approved of a commercial/industrial land use scenario and ICs are in place to this effect. In this case, the Department will allow substitution of the commercial/industrial exposure parameters in the soil equations to take into account reduced exposure to hazardous substances under commercial/industrial use of a site. Additional discussion of a soil ingestion factor for a commercial/industrial site is provided in Section 6.5 of this document. Other regulatory requirements, such as ICs, may apply. The parameters that can be modified and the commercial/industrial values that can be used are listed in Table 3.

6.8 Other Method Three Calculations

6.8.1 Site Specific Saturation Limit

A soil cleanup level may be capped at saturation where the calculated human health cleanup level in Table B1 or B2 is above the saturation limit. The purpose for capping at saturation is to limit the presence of a contaminant as a non-aqueous phase liquid (NAPL), which per 18 AAC 75.325(f) must be recovered to the maximum extent practicable. A site-specific saturation concentration for individual contaminants (C_{sat}) can be calculated using the equation in section 5.4 of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) using site-specific soil data (bulk density; total, air-filled and water-filled porosities; and total organic carbon).

6.8.2 Developing a Cleanup Level for a Contaminant Not Listed in Regulation

For contaminants or pollutants not listed in Tables B1, B2, or C, a cleanup level for soil and groundwater can be developed under 18 AAC 75.340(g) or 18 AAC 75.345(b)(3) using the department's *Risk Assessment Procedures Manual* (ADEC, 2015) and in consultation with the department's technical staff. The resulting groundwater cleanup level can be used in calculating a migration to groundwater cleanup level for soil that is protective of the groundwater.

7.0 Input Parameters

The *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) lists the equations and the input parameters used to calculate the cleanup levels presented in Table B1 and Table B2. The input parameters describe exposure to a hazardous substance in a contaminated media or site conditions that affect the fate and transport of contaminants at a site. Soil and aquifer parameters described in Tables 1-3 of this guidance can be modified to take into account site conditions not represented by the default parameter values. The following sections discuss the input parameters in more detail, including how they are derived and calculated.

7.1 Exposure Parameters

Exposure parameters are values used to describe the amount and duration of exposure to a contaminant at a site. Exposure parameters can be modified under method three as described in Section 6.5. The Department uses EPA values for residential and commercial/industrial exposure parameters except where noted. Each exposure parameter used in calculating the method two and method three soil cleanup levels is discussed below.

7.1.1 Averaging Time

The averaging time is the number of days in a year multiplied by the exposure duration over which exposure is averaged. For carcinogens, exposure is averaged over an estimated lifetime determined by EPA to be 25550 days (70 years) (EPA, 1989). For example, although exposure to a carcinogenic contaminant in soil is assumed to take place over 26 years under a residential exposure scenario, the risk of getting cancer that can be attributed to this exposure is determined over the individual's lifetime, 70 years.

For noncarcinogens, the averaging time equals the length of exposure to the contaminant at the site, because the assessment is based off an assumed dose where no effect occurs or a threshold. Under a residential exposure scenario for noncarcinogens, a child resident is used and assumed to be exposed to contaminants in soil for 2190 days (6 years) since more exposure takes place from ages one to seven (EPA, 1989).

The averaging time can be modified for noncarcinogenic hazardous substances under method three if the department approves a commercial/industrial land use scenario for the site. In this case, the exposure duration can be changed from 6 years for residential child to 25 years, an estimate of the length of time an individual would work at a commercial/industrial site.

7.1.2 Body Weight

Body weight is used in conjunction with the toxicity value, measured in milligrams (mg) of contaminant ingested per kilogram (kg) of body weight per day or meters³ (m³) of contaminant inhaled per kilogram of body weight, to determine the daily exposure to a hazardous substance. For noncarcinogenic contaminants in soil under a residential land use scenario, the body weight is set at 15 kg, an average child body weight. The value used for carcinogenic hazardous substances in soil under a residential land use scenario takes into account an age-adjustment for the child and adult for the lifetime assessment.

Body weight can be modified for a hazardous substance under method three if the department approves a commercial/industrial land use scenario for the site. In this case, the Department may approve modifying the body weight value from 15 kg (noncarcinogenic) or age adjusted (carcinogenic) to 80 kg, as listed in Table 3.

7.1.3 Exposure Duration

The exposure duration is the number of years over which exposure occurs. The exposure duration for the ingestion of noncarcinogenic contaminants under a residential land use scenario is set at 6 years. For carcinogens, the exposure duration is set at 26 years, except for petroleum, which is set at 30 years, a high-end estimate of the amount of time an individual resides in one residence.

This value can be modified under method three if the Department approves a commercial/industrial land use scenario for the site. In this case, the exposure duration can be set at 25 years for both noncarcinogenic and carcinogenic compounds as listed in Table 3.

7.1.4 Exposure Frequency

The exposure frequency is the number of days per year an individual is exposed to a contaminant. This value is set for each climate zone based on a conservative estimate of the number of days of non-exposure due to snow cover. For the Arctic zone, the exposure frequency is set at 200 days per year, corresponding to approximately 5 months of snow cover eliminating exposure. For the Under 40" zone, the exposure frequency is set at 270 days per year, corresponding to a minimum of three (3) months of snow cover eliminating exposure. For the Over 40" zone, the exposure frequency is set at 330 days per year, corresponding to approximately one month of snow cover eliminating exposure.

This value should not be modified under method three unless the Department approves a commercial/industrial land use scenario. In this case, a value of 250 days per year can be used. This value is more conservative than the default value used for calculating cleanup levels for the Arctic zone. Therefore, it is recommended that the default value of 200 days per year be used for commercial/industrial sites in the Arctic zone. The use of a site-specific exposure frequency other than the default or commercial/industrial exposure frequency values can be proposed under method four. The information provided to the department under a risk assessment is used to determine whether another exposure frequency value is protective of human health.

7.1.5 Ingestion Rate/Factor

For the ingestion route, equations use an age-adjusted approach to account for the variation in soil ingestion rates for children depending on age for carcinogenic contaminants. A number of studies have shown that inadvertent ingestion of soil is common among children six years old and younger (Calabrese et al. 1989, Davis et al. 1990, Van Wijnen et al. 1990). Therefore, the dose method uses an age-adjusted soil ingestion factor that takes into account the difference in daily soil ingestion rates, body weights, and exposure duration for children from 1 to 6 years old and residential adults from 7 to 26 years old.

For noncarcinogen where assessment is based on a threshold the higher daily rates of soil ingestion in children of 200 mg per day is taken into account for a health protective approach.

The ingestion rate can be modified under method three if the Department approves a commercial/industrial land use scenario for the site. In this case, the commercial/industrial exposure parameter values provided in Table 3 may be substituted into the equations. For a commercial/industrial scenario, an ingestion rate of 100 mg per day for 25 years for an outdoor worker ages may be used or 50 mg per day for an indoor worker.

7.1.6 Oral Reference Dose and Oral Slope Factor

An oral reference dose expresses the concentration of a contaminant via daily exposure through the oral route for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious noncarcinogenic effects over the period of exposure (EPA, 1998). This toxicity parameter is used in the residential soil equations to calculate the soil cleanup levels for the ingestion of noncarcinogenic hazardous substances in soil. The values used to calculate default cleanup levels for the hazardous substances listed in Table B1 and Table B2 are listed in Appendix A of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a).

The oral slope factor expresses the carcinogenic risk per milligram of chemical ingested per kilogram of body weight per day (EPA, 1998). This toxicity parameter is used to calculate the soil cleanup levels for the ingestion of carcinogenic hazardous substances in soil. The value used to calculate each default soil cleanup level is listed in Appendix A of *Procedures for Calculating Cleanup Levels* (ADEC, 2016a). When developing a cleanup level under method three for a contaminant not listed in Table B1, the toxicity value used shall be selected based on the process described in the department's *Risk Assessment Procedures Manual* (2015).

There are some hazardous substances that have both noncarcinogenic and carcinogenic effects for this route of exposure. Therefore, both an oral reference dose and an oral slope factor may be listed. If a cleanup level for the ingestion pathway is being calculated for these types of hazardous substances, then both sets of equations must be used to calculate a noncarcinogenic-based and a carcinogenic-based soil cleanup level. The most conservative cleanup level applies for this route of exposure at the site. This circumstance is automatically accounted for in the department's Cleanup Levels Calculator.

7.1.7 Reference Concentration and Unit Risk Factor

A reference concentration expresses the concentration of a contaminant via daily exposure through inhalation for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious noncarcinogenic effects over the period of exposure (EPA, 1989). This toxicity parameter is used to calculate the soil cleanup levels for the inhalation of noncarcinogenic hazardous substances in soil. The value used to calculate the default cleanup level is listed in Appendix A of *Procedures for Calculating Cleanup Levels* (ADEC, 2016a).

The unit risk factor is the carcinogenic risk per microgram of contaminant per cubic meter of air inhaled (EPA, 1989). This toxicity parameter is used in the equations to calculate the soil cleanup levels for the inhalation of carcinogenic volatile hazardous substances in soil. The unit risk factor used to calculate each default cleanup level is found in Appendix A of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a).

There are some hazardous substances that have both noncarcinogenic and carcinogenic effects for this route of exposure. Therefore, both a reference concentration and a unit risk factor may be listed in Appendix A for a hazardous substance. If a cleanup level for the inhalation pathway is

being calculated for these types of hazardous substances, then both a carcinogenic-based and a noncarcinogenic-based soil cleanup level should be calculated. The most conservative cleanup level applies for this route of exposure at the site. The department's Cleanup Levels Calculator does this automatically.

7.1.8 Target Cancer Risk

The target cancer risk is a numerical value that statistically describes the number of individuals that would likely get cancer attributed to exposure to a site under the established exposure assumptions over and above the general rate of cancer attributable to non-site causes of exposure (EPA, 1989). This parameter is used to calculate cleanup levels for carcinogenic hazardous substances for ingestion and the inhalation pathways. The department's target cancer risk factor is 1×10^{-5} , which translates to one individual in 100,000 individuals exposed to a site for 26 years under the residential scenario that would likely get cancer in their lifetime attributable to exposure to a carcinogenic contaminant at a site.

7.1.9 Target Hazard Quotient

The target hazard quotient is the ratio of the estimated intake rate of a chemical to the estimated rate of intake at which there is no observable adverse effect. This parameter is used to calculate cleanup levels for noncarcinogenic hazardous substances for the ingestion and inhalation pathways. The Department's target hazard quotient is 1, calculated to one significant figure.

7.2 Soil Parameters

The soil and aquifer parameter values used to develop the Department's default cleanup levels may not be reflective of actual soil or aquifer conditions at a particular site. Therefore, method three allows for the use of site-specific data for selected parameters. The Department requires submittal of the parameters proposed for modification, the site-specific values for those parameters proposed for use and a description of the basis for each site-specific value prior to calculating alternative cleanup levels. The information should be summarized in a tabular format and submitted to the Department using a similar format to that provided in Table 4 at the end of this document. The department will review the proposed values to ensure that each value reflects the site soil or aquifer conditions at the appropriate location and depth. For values developed from soil or aquifer samples, the location of the samples used to determine this soil parameter should be consistent with soil and aquifer conditions where the contamination is present at a site. For example, if the migration to groundwater cleanup level applies at a site, then the soil parameter should be determined on subsurface soil samples as close to the water table as is technical practical. However, if an inhalation level applies, then a soil parameter should be determined from surface and subsurface soil samples to a depth of 15 feet. Site specific aquifer values should be developed from samples obtained from the aquifer, not from vadose zone soil data. The number of samples that require analysis should be determined site specifically, depending on the size and heterogeneity of the site.

The following soil parameters may be modified under method three.

7.2.1 Dry Bulk Density

The dry bulk density is the weight of the soil after oven drying at 105° Centigrade to a constant weight divided by the volume of the soil, including pore volume (Bates and Jackson, 1987). This parameter can be determined through laboratory analysis of soil samples or in the field using a nuclear densometer. Soil particle density is not input into the Petroleum Cleanup Levels Calculator or the Cleanup Levels Calculator, but is used for total porosity calculations and is also determined/reported with the dry bulk density methods. However, if a site specific value for soil particle density is used, the value and how it is derived must be reported in the alternative cleanup level documentation.

7.2.2 Total Soil Porosity

The total soil porosity is the degree to which soil is permeated with pores or cavities through which water or air can move and is the sum of the water-filled and air-fill porosities (EPA, 1998). This parameter is not an input parameter, but is directly related to the air-filled and water-filled porosities. The total soil porosity can be determined either through a laboratory test, a tabled value based on the soil type or can be calculated from the dry bulk density and the soil particle density. Therefore, if a site-specific dry bulk density is used, then a corresponding total soil porosity should be determined.

If a site-specific water-filled porosity is calculated based on the moisture content and the dry bulk density, then the total porosity and the air-filled soil porosity values should be reviewed to ensure that the sum of the air-filled and water-filled porosities equals the total soil porosity. If the porosity is determined from the soil type using a tabled value, the reference for the table should be a published, peer-reviewed reference and should be provided to the department for approval.

If a site-specific porosity is used, the bulk density value should be reviewed to ensure that the two parameters describe the same type of soil. If the porosity is determined from a peer-reviewed reference, then the bulk density should be consistent with the reference porosity value.

$$\% \text{ solid space} = (\text{bulk density} / \text{particle density}) \times 100$$

$$\% \text{ porosity} = 100 - (\% \text{ solid space})$$

7.2.3 Water-Filled Porosity

The water-filled soil porosity is the portion of the total porosity containing water. This value can be calculated as the product of the moisture content of a soil multiplied by the dry bulk density. This value should be determined site-specifically if a site-specific dry bulk density or moisture content is determined. Variation in this parameter directly affects the air-filled soil porosity; therefore, if this parameter is determined site specifically, the air-filled porosity and total porosity must also be determined site specifically.

7.2.4 Air-Filled Soil Porosity

The air-filled soil porosity is the portion of the total porosity of soil containing air. This value is calculated by subtracting the water-filled porosity from the total soil porosity. If a site-specific total soil porosity or water-filled soil porosity is determined for a site, then the air-filled soil porosity should be reviewed to ensure that the sum of the air-filled and water-filled soil porosities equals the total soil porosity.

7.2.5 Fraction of Organic Carbon

The fraction of organic carbon (foc) can be best defined as the portion of organic matter in the soil that is available to adsorb organic contaminants of concern at a site. The higher the organic carbon content, the more organic contaminants will adsorb to it, reducing the concentration that can migrate to groundwater. In order to calculate a site-specific foc, RPs must collect enough soil samples adjacent to the area of contamination to derive a foc 95% lower confidence level (LCL) of the mean. This number is then used in place of the default fraction organic carbon input parameter in the soil-water partitioning equation when determining a site-specific migration to groundwater cleanup level. In instances with high foc variability (e.g. relative standard deviation greater than 100 percent), the department may specify the use of the lowest measured foc result. The appropriate sampling and analysis method may vary by site, for information on sample collection and analysis consult the technical memorandum, *Determining the Fraction of Organic Carbon for Methods Three and Four* (ADEC, 2017c).

At sites where numerous source areas are present, specific cleanup level determinations may be required by the ADEC project manager for each individual area. Therefore, separate foc samples may need to be collected for some or all of the source areas within a site unless the responsible party demonstrates that similar soil types exist at some or all of the contaminated areas.

Supporting documentation must be provided to the department for the proposed site specific foc value. Supporting documentation includes, at a minimum, a narrative of site characterization activities, a diagram depicting boring or test pit locations and sample collection depths in relation to the contaminated soil mass, boring logs or test pit descriptions and soil description for foc and contaminated zone sampling points; tabulated sample results, laboratory reports including results of all foc analyses; and the proposed site-specific foc value.

7.2.6 Average Soil Moisture Content

The average soil moisture content is the percent moisture contained in a soil sample as determined as the weight difference between the as-collected weight of soil collected outside of the saturated zone and the oven-dried weight (Bates and Jackson, 1987). This parameter is used to calculate the water-filled porosity. The default values are 10% for surface soil and 20% for subsurface soil.

7.3 Aquifer Parameters

The following parameters may be modified in calculating a site-specific dilution factor and mixing zone depth (petroleum only).

7.3.1 Aquifer Thickness

The aquifer thickness is the thickness of the aquifer impacted by leachate from the overlying vadose zone soil. The depth of an aquifer can be determined from boring or monitoring well logs if they were completed at a depth sufficient to determine the depth of the aquifer. Other data, such as knowledge of the depth to permafrost, historical well log data or information from the United States Geographical Survey (USGS), may be used in demonstrating the thickness of an aquifer.

7.3.2 Dilution Factor

This parameter is used to determine the dilution that occurs when leachate from contaminated soil enters clean groundwater. This parameter can be calculated using site-specific soil and aquifer data.

7.3.3 Hydraulic Conductivity

Hydraulic conductivity is the rate at which water can move through a permeable medium (i.e., the coefficient of permeability) in the saturated zone (EPA, 1998). This parameter can be determined in the field using a slug or pump test, in a lab using ASTM D5084-16a *Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter* (ASTM 2016), or from a tabled value based on the aquifer soil type. The soil type should be determined for the area of the aquifer under investigation, consisting of the impacted portion of the aquifer (source area) up to and including the downgradient edge of the source area, rather than the vadose zone or the aquifer at different depths or locations from the area of impact. The hydraulic conductivity for a specific soil type may consist of a range of values that vary by several orders of magnitude.

In general, the department will only accept the most stringent tabled hydraulic conductivity for a particular soil type. The reference for a tabled hydraulic conductivity should be a published, peer-reviewed reference and should be provided to the department for approval. The Department will also accept a calculated hydraulic conductivity using the Hazen method for sands with an effective grain size (d_{10}) between approximately 0.1 and 3.0 mm (Fetter, 1994) and the Kozeny-Carman method for grain size >3.0 mm. Other methods may also be acceptable depending upon soil types (Odong, 2007). The effective grain size is typically reported when a sieve analysis is performed on a soil sample in accordance with T 88 of the *American Association of State Highway and Transportation Officials* (AASHTO). Equations for calculating hydraulic conductivity are shown below:

$$\text{Hazen: } K = \frac{g}{v} \times 6 \times 10^{-4} [1 + 10(n - 0.26)] d_{10}^2$$

$$\text{Kozeny-Carman: } K = \frac{g}{v} \times 8.23 \times 10^{-3} \left[\frac{n^3}{(1-n)^2} \right] d_{10}^2$$

7.3.4 Hydraulic Gradient

The hydraulic gradient is the change in total head with a change in distance in a given direction yielding a maximum rate of decrease in head (modified from Bates, R.L. and Jackson, J.A, 1987). In general, the hydraulic gradient is the direction of groundwater flow due to changes in elevation of the water table. If a site-specific hydraulic gradient is determined, it should be based on a minimum of three water elevation data points placed in a triangular configuration so the direction of maximum flow can be determined. The department may also accept as one of the water elevation data points, a water elevation for a surface water body located on or adjacent to the site. The department will

consider factors such as whether the surface water body is hydraulically connected to the groundwater at the site and whether there is seasonal fluctuations in the surface water elevation in making a determination to allow the use of surface water elevation data. The hydraulic gradient may need to be determined for different hydrogeographical areas at the site or at different times due to seasonal variations in groundwater flow. The hydraulic gradient value that applies is the most conservative hydraulic gradient determined for a site. The applicable hydraulic gradient in areas of large seasonal variation may need to be determined in consultation with the project manager.

The EPA provides an interactive spreadsheet tool for easily calculating hydraulic gradients called 3PE (Beljin et al, 2014), which is additionally well suited for evaluating temporal trends.

7.3.5 Infiltration Rate

The infiltration rate is the amount of precipitation that enters the soil column averaged on a yearly basis, measured in meters per year. A site-specific infiltration rate can be determined by assuming that infiltration is 1/5 of the average annual precipitation rate for the site or by using an approved model. The department will accept data on the average annual precipitation rate from the NOAA National Centers for Environmental Information 1981-2010 Climate Normals available at: <http://www.ncdc.noaa.gov/cdo-web/datatools/normals>; the Western Regional Climate Center available at: <http://www.wrcc.dri.edu/summary/Climsmak.html>; or another source approved by the Department. The source should provide sufficient data to establish a trend of average annual precipitation in the geographic locality of the site.

7.3.6 Mixing Zone Depth

The mixing zone depth may only be modified for petroleum compounds. It can be determined using the equation in Section 6.8 of *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) and site specific soil and aquifer parameters. The resulting mixing zone should not exceed the aquifer thickness. If the aquifer thickness is exceeded, then the mixing zone should be capped at the aquifer thickness.

7.3.7 Source Length Parallel to Groundwater Flow

The source length parallel to groundwater flow is the dimension of the areal extent of soil contamination in the direction of groundwater flow. This parameter can be determined site specifically if there is sufficient subsurface soil data from either soil boring or monitoring well logs to determine the areal extent of subsurface soil contamination. The Department is unlikely to approve an alternative cleanup level without sufficient site information, so this parameter should, at a minimum, be approximated prior to developing alternative cleanup levels. The maximum length of the source parallel to the direction of groundwater flow should be used in calculating a site-specific mixing zone depth and dilution factor.

8.0 Climate Zones and the Cleanup Levels Equations

The following discusses the climate zones and soil cleanup level equations presented in the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a) used in calculating the default soil cleanup levels for Method two. In addition, used to calculate cleanup levels for groundwater are also discussed, although not part of a method three alternative soil cleanup level calculation. A more detailed

discussion of the development of the EPA soil cleanup levels equations can be found in *the Soil Screening Guidance: User's Guide* (EPA, 1996a) and *Soil Screening Guidance: Technical Background Document* (EPA, 1996b).

8.1 History of the Climate Zones

In the mid-1990s, the department hired a contractor to perform a statistical analysis of the University of Alaska Anchorage, Environment and Natural Resource Institute's September 1992 "Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days for 1961 - 1990" statewide weather data report. The resulting three climate zones were: "Arctic" (continuous permafrost), "Under 40 Inch Zone" (that area of the state receiving less than 40 inches of annual precipitation), and "Over 40 Inch Zone" (that area of the state receiving more than 40 inches of annual precipitation). The latter two zones had a mean plus one standard deviation annual precipitation of 26.1 and 121.1 inches per year respectively. These precipitation values were used to develop zone-specific parameters for the soil-water partitioning equations that generate the migration to groundwater cleanup levels. However, in 2008, based on conversations with state and federal officials, database and library research, and field measurements, the department transitioned to a single set of input parameters that represented default conditions statewide for migration to groundwater (for Table B1 only). The values for parameters for the under 40-inch zone were used because this zone represents the majority of the state.

Each zone was also assigned a conservative estimate of the reasonable exposure frequency to contaminated soil for an individual within that geographic area. This analysis looked at temperature, snowfall, and past the department's risk assessment data within each zone. This analysis showed that average temperature and snowfall affected potential exposure in a manner that most other states do not have to be concerned with. For example, a preliminary analysis showed that a reasonable estimate for snow cover was slightly over five months in the Arctic Zone; three months in the Under 40 Inch Zone; and one month in the Over 40 Inch Zone. These exposure estimates based on snow cover are not representative of every location within a particular zone. They are not designed to be. They are, however, low-end conservative estimates representative of the reasonable exposure for the zone as a whole. The resulting exposure frequency values used to develop the soil cleanup standards were 200 days in the Arctic Zone (160 days non-exposure time), 270 days in the Under 40 Inch Zone (90 days non-exposure time), and 330 days in the Over 40 Inch Zone (30 days non-exposure time).

Standardized default exposure parameters developed by the EPA were used except for exposure frequency as outlined above. Default parameters such as soil bulk density and porosity are derived from EPA's 2002 *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (EPA, 2002). Conservative representative Alaskan specific soil parameters were also developed. For default input values and sources, consult the department's *Procedures for Calculating Cleanup Levels* (ADEC, 2016a).

8.2 Human Health Exposure Pathways

As described earlier in this document, the soil cleanup levels for human health are calculated to be protective of three exposure pathways -- inhalation of volatiles and particulates; ingestion, and dermal contact -- using three sets of equations for carcinogenic, noncarcinogenic and mutagenic risks, where these modes of action apply for each compound. The resulting value is the cumulative risk of exposure through all three pathways. The assumptions that are used in the equations for

each type of exposure are discussed below. The human health equations for inhalation, ingestion and dermal contact with soil are presented in Section 3.0 of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a).

When the calculated soil cleanup levels for human health is greater than the soil saturation concentration, the cleanup values is set at the soil saturation concentration. The saturation concentration is a level at which the contaminant has been completely absorbed to the soil and free product is predicted to exist in the soil beyond the saturation limit. The department requires that free product be removed to the maximum extent practicable. Therefore, hazardous substances in soil cannot exceed the saturation concentration.

8.2.1 Inhalation of Hazardous Substances

This exposure pathway addresses the inhalation of contaminants in ambient outdoor air; it does not account for vapor intrusion pathway. The inhalation cleanup level calculation is designed to be protective of the inhalation of ambient air above soil contaminated with hazardous substances for an individual residing at a contaminated site for 26 years. This includes the inhalation of compounds considered volatile, which are those chemicals with a Henry's Law constant greater than or equal to $1 \times 10^{-5} \text{ atm}\cdot\text{m}^3/\text{mole}^2$ or a vapor pressure greater than or equal to 1 mm Hg, and the inhalation of fugitive dust from non-volatile compounds, using a particulate emission factor (PEF) equation. The following assumptions were used in developing the inhalation equations (EPA, 1996a):

- No free product is present;
- No reduction in contaminant concentration due to natural process or source removal, i.e., an infinite source; and
- Vapor phase diffusion is the only transport mechanism from the soil column to ambient air (nonvapor-phase diffusion and flow due to capillary action are not considered)

The exposure parameters in these equations can be modified under method three if the Department has approved a commercial/industrial land use scenario. If a commercial/industrial land use scenario is approved for a site, the exposure parameters in Table 1 can be used in these equations under method three. In addition, approved site-specific soil data may be substituted for the soil parameters listed in Table 1 of this document for the corresponding equations in the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a).

8.2.2 Ingestion of Contaminants in Residential Soil

This human health pathway addresses exposure to contaminants through the ingestion of soil under a residential land use scenario. For noncarcinogens, it is assumed under this scenario that 200 mg of soil is ingested per day for 200 days per year, 270 days per year, or 330 days per year, depending on which zone a site is located in, for six years. For carcinogens, it is assumed under this scenario that 114 mg of contaminated soil is ingested per day for 200 days per year, 270 days per year, or 330 days per year, depending on which zone a site is located in, for 26 years. The exposure parameters in these equations can be modified under method three if the Department has approved a

² The $\text{atm}\cdot\text{m}^3/\text{mole}$ units are obtained by multiplying the unitless value by 0.02446 (which comes from multiplying the gas constant ($0.0000802 \text{ atm}\cdot\text{m}^3/\text{mole}\cdot\text{K}$) by the temperature (298.16 K)).

commercial/industrial land use scenario. If a commercial/industrial land use scenario is approved for a site, the commercial/industrial exposure parameters in Table 3 can be used in these equations under method three.

8.2.3 Dermal Contact with Hazardous Substances

The cleanup level equations for this pathway account for risks through the dermal exposure pathway according dermal absorption values derived from RAGS Part E for a given compound, exposure duration values based on snow cover estimates in each climate zone-- 200 days per year for the Arctic zone, 270 days per year for the <40" zone, or 330 days per year for the >40" zone-- and skin surface area default values. See Table 8 in Appendix B of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a).

8.3 Derivation of the Soil Saturation Limit

This equation is used to predict the concentration at which hazardous substances have saturated soil pore air and pore water and the adsorptive limits of the soil have been reached. Above this concentration, the hazardous substance may be present as free phase product. The inhalation equations are not valid if free product is present because the Henry's Law constant, H', does not apply when contaminants are present in free phase (EPA, 1996a). Therefore, if an alternative cleanup level is being calculated for a hazardous substance, then a saturation limit concentration should be calculated with the site-specific soil data used to calculate the alternative soil cleanup level. The department requires that the more stringent of the alternative cleanup level or soil saturation limit applies.

8.4 Groundwater Cleanup Level Equations

The groundwater cleanup calculations are broken down into equations for ingestion of groundwater, dermal contact with groundwater, and inhalation of volatiles from groundwater. Separate equations are used to calculate cleanup levels for compounds with carcinogenic, non-carcinogenic, and/or mutagenic risks. See Section 2.0 of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a). Site specific cleanup levels may not be calculated for groundwater, except where noted in 18 AAC 75.345.

8.5 Soil-Water Partitioning Equation for Migration to Groundwater

The migration to groundwater criteria for the Table B1 and B2 compounds are derived using a soil-water partitioning equation (Section 4.0 of *Procedures for Calculating Cleanup Levels* (ADEC, 2016a). The equations assume that the contaminants in the soil column exist in three phases, i.e., the hazardous substance is adsorbed to organic carbon in the soil column, is in the gas phase in the soil pores, and is in the dissolved phase in the soil pore water. For more information on the soil-water partitioning equation, consult the department's technical memorandum, *Soil-Water Partitioning Equation* (ADEC, 2008).

A single set of migration to groundwater criteria apply statewide for Table B1, and are based on conservative assumptions about fate and transport mechanisms in the subsurface, accounting for both (1) release of a contaminant in soil leachate and (2) transport of the contaminant through the underlying soil and aquifer to a receptor well (U.S. EPA. 2012). The soil cleanup levels for the

migration to groundwater pathway are considered protective of groundwater used as a current or reasonably expected potential future source of drinking water underlying contaminated soil in contact with the groundwater. The groundwater cleanup levels are found in Table C. These values are used in calculating the migration to groundwater cleanup levels for the overlying soil. Therefore, Table C groundwater cleanup levels apply if using method two for determining the soil cleanup level for the migration to groundwater. If another cleanup level for groundwater is approved, method three can be used to incorporate an alternative groundwater cleanup level into the development of a migration to groundwater cleanup level for soil.

In order to calculate an alternative migration to groundwater cleanup level, a target leachate concentration must first be calculated. The target leachate concentration is calculated by multiplying the groundwater cleanup level listed in Table C by the dilution attenuation factor (DAF). The DAF accounts for dilution and attenuation that occurs when the target leachate concentration enters the drinking water aquifer and travels to the downgradient edge of the contaminant source. DAF is determined by multiplying the dilution factor (DF) with attenuation factor (AF) ($DAF = DF \times AF$). The DF is determined using the equation in Section 5.5 of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a). The standard AF used to determine the cleanup standards is: $AF = 4$. The AF may be modified on a chemical-specific basis to take into account for attenuation processes such as biodegradation, first-order decay, volatilization, or other attenuation processes; however, this will require an appropriate fate and transport model that evaluates such processes to generate a predicted site-specific attenuation factor (EPA 1996b).

The dilution factor equation models the dilution that occurs when soil leachate enters clean groundwater. This equation assumes a mixing zone depth determined using the second equation in Section 5.5. The standard default mixing zone depth used to determine the cleanup standards is: $d = 5.5$ m. This is a fixed value and cannot be modified site-specifically for Table B1 compounds. The dilution factor can be calculated site-specifically for both Table B1 and B2 compounds, but the mixing zone can only be adjusted for Table B2. For the Table B2 mixing zone equation see Section 6.8 of the *Procedures for Calculating Cleanup Levels* (ADEC, 2016a). The soil and aquifer parameter values used in each equation should be determined from soil samples taken from the appropriate depth, and the same value for each parameter common to both equations should be used. The calculated mixing zone depth should not exceed the aquifer depth. If the calculated mixing zone depth exceeds the aquifer depth value, then the mixing zone depth should be capped at the aquifer depth value.

The assumptions below were used to develop the migration to groundwater equation, dilution factor and mixing zone equations. The methodology is designed to apply to a broad range of sites where information about subsurface conditions may be limited. Because of this constraint, the methodology is based on conservative, simplifying assumptions about the release and transport of contaminants in the subsurface (EPA, 1996a). Therefore some of the assumptions may not be correct for a given site though the equations can still be relevant when used with site-specific information. However, more complex models may be superior for addressing unique site conditions that do not follow those below and to calculate alternative cleanup levels that are more appropriate for a given site.

- Infinite source (no reduction in contaminant concentration due to natural process or source removal, that is, the dissolved concentration emanating from the source area does not decrease through time)
- Uniformly distributed contamination from surface soil to the top of the aquifer;
- The source is entirely within the vadose zone (no portion of the source is submerged at any time of the year).
- Infiltrating precipitation is in equilibrium with the source and carries dissolved contaminants to the water table.
- No contaminant attenuation (i.e., adsorption, biodegradation, chemical degradation) or dilution in soil;
- Instantaneous soil/water partitioning (solubility is not considered);
- Unconfined, unconsolidated aquifer that is homogeneous;
- Receptor well is located at the downgradient edge of the source area and screened within the plume;
- The DAF applies over a “mixing zone” depth, which is a characterization of the maximum depth of contaminant migration at the downgradient edge of the source area (that is, contaminants from the source zone will not be carried below the mixing zone depth at the downgradient edge of the source area—contaminants may be carried below the mixing zone depth downgradient of the source area).
- The DAF relates the average concentration within the mixing zone depth to the source concentration. Note that shallow portions of the mixing zone will be above this average concentration and the deeper portions of the mixing zone will be below the average concentration; and
- No free product is present.

Flow Path of Infiltrating Precipitation and Mixing Zone Depth Due to Downward Velocity of Infiltrating Precipitation. (No Dispersion)

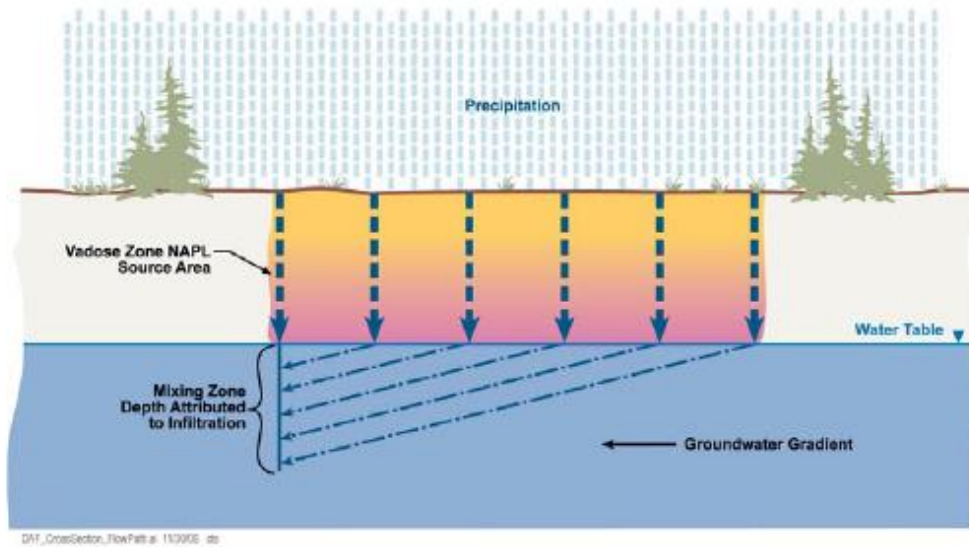


Figure 2 Current EPA & ADEC Dilution Model -- Mixing Zone Depth Due to Downward Velocity of Infiltrating Precipitation

Depth of Hydrocarbon Migration Due to Infiltration and Dispersion

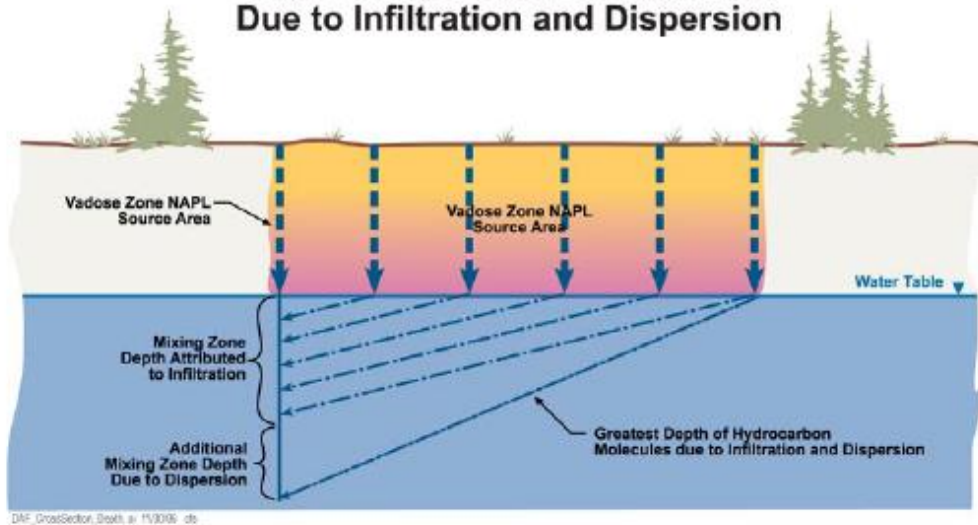


Figure 3 Current EPA & ADEC Dilution Model-- Mixing Zone Depth Due to Downward Velocity of Infiltrating Precipitation + Hydrodynamic Dispersion

Table 4. – Sample Table for Presentation of Site-Specific Values for Parameters*

Parameter	Default Value (units)	Proposed Value (units)	Source/Method of Collection
Organic Carbon, <i>foc</i>	0.001	0.015	Site specific data collected and analyzed via the Walkley Black method and following the DEC 2017 Memo on Determining Fraction of Organic Carbon..
Hydraulic conductivity, K	876 (m/yr)	300 (m/yr)	Tabled value based on most conservative soil type determined by sieve analysis of representative field samples. Freeze, R.A. and Cherry, J. A., Groundwater, Table 2.2

*Use this table or a similar format to list the variables for which site-specific data has been collected, and identify the source of the data and if collected from the site, include the methods for how it was collected.

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