User's Guide for MTCASGL Workbook Version 12.0

Workbook Tools for Calculating Soil and Groundwater Cleanup Levels under the Model Toxics Control Act Cleanup Regulation

Toxics Cleanup Program

Washington State Department of Ecology
Olympia, Washington

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Related Publications and Resources

User's Guide for MTCATPH Workbook Version 12.0 - Workbook Tools for Calculating Soil and Groundwater Cleanup Levels under the Model Toxics Control Act Cleanup Regulations[i]; *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*[ii]; CLARC Guidance[iii]; *Toxicity data and physical/chemical properties for petroleum mixtures*[iv]; *Guidance for Silica Gel Cleanup in Washington State*[v]; *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*[vi]; *Analytical Methods for Petroleum Hydrocarbons*[vii]; *Implementation Memo #10*[viii]; *Implementation Memo # 23*[ix]

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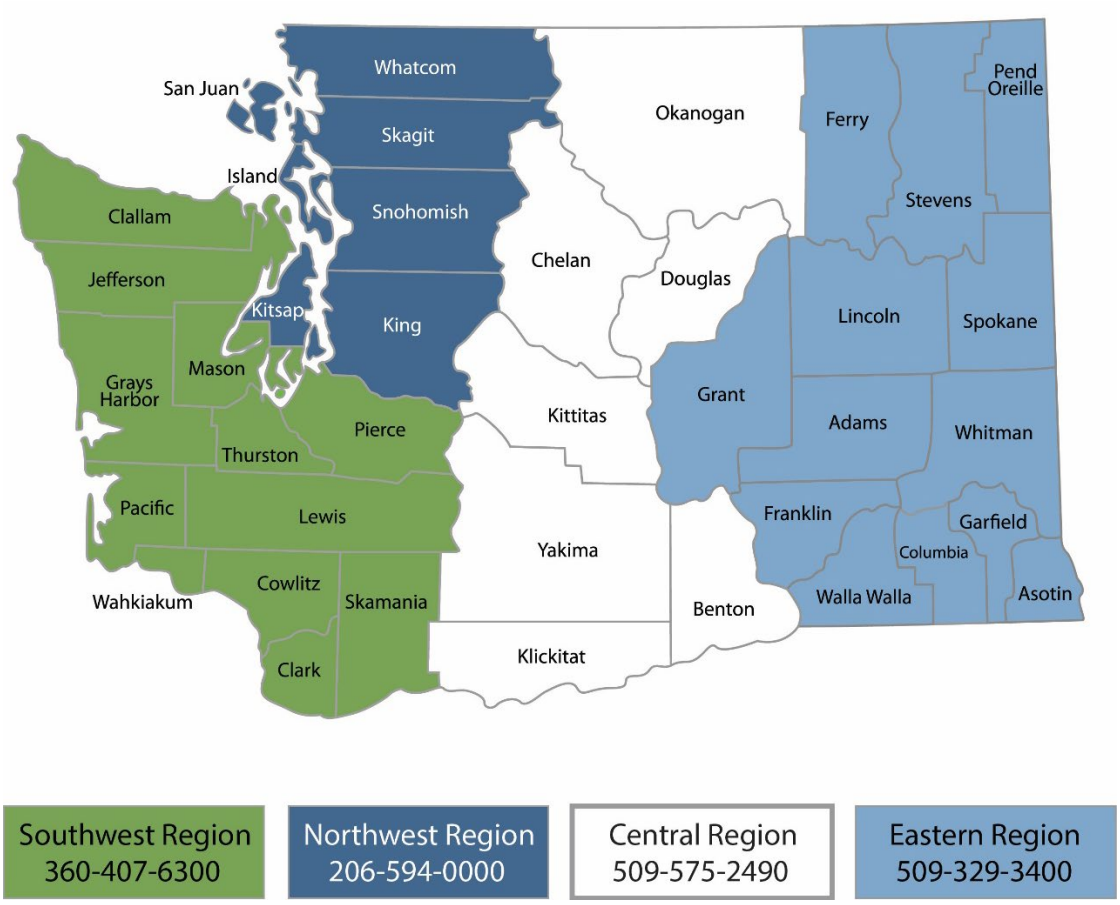
Department of Ecology's Regional Offices

Map of Counties Served



Region	Counties served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
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State of Washington

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Chapter 1. Introduction

The Model Toxics Control Act (MTCA) Cleanup Regulation, Chapter 173-340 WAC[xi], sets forth the requirements and procedures for establishing cleanup levels that are protective of human health and the environment. The purpose of the MTCASGL User's Guide is to introduce the user to the features of the MTCASGL Excel-based workbook (Workbook) for calculating Soil and Groundwater Cleanup Levels for individual hazardous substances. The MTCASGL User's Guide is arranged as a set of tutorials that allow the user to learn the basics of the Workbook in a "hands-on" environment.

The Workbook described herein provides tools for the calculation of Method B and Method C[1] cleanup levels for soil and groundwater based on protection of human health for individual hazardous substances.

1.1 Overview of the MTCASGL Workbook Version 12.0

The MTCA regulation provides for the establishment of both **standard** and **modified** Methods B and C cleanup levels.

- Under **standard** Methods B and C, protective concentrations are calculated using standard equations and default assumptions provided in the regulation. Protective concentrations calculated for individual hazardous substances under standard Methods B and C are published in Ecology's Cleanup Levels and Risk Calculations (CLARC)[xii] data tables.

- Under **modified** Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The regulation specifically describes which parameters may be adjusted and how they may be adjusted. The Workbook described herein provides the necessary tools for calculating protective soil and groundwater concentrations under modified Method B or Method C.

The MTCASGL Workbook allows the user to use pre-established chemical and toxicity data, default exposure assumptions, and site-specific information to calculate any of the following for a **single chemical contaminant**:

- **Hazard and risk under current conditions**: The Workbook provides the tools necessary to calculate the noncancer HQ and risk under current conditions. To do this, the

[1] Method C groundwater cleanup levels based on potable water ingestion may only be used at sites qualifying under the strict conditions set forth in WAC 173-340-706(1).Contact Ecology for methods to evaluate hazardous substances in groundwater that may qualify for a Method C groundwater cleanup level.

Workbook requires the user to enter a measured soil or groundwater concentration for a single chemical contaminant. The Workbook then executes a "forward" calculation using the equations in the regulation and solving for noncancer HQ and risk. For soil measurements, the Workbook calculates the noncancer HQ and risk corresponding to the direct contact pathway, the leaching pathway (protection of groundwater), and the vapor pathway (protection of air quality). For groundwater measurements, the Workbook calculates the noncancer HQ and risk corresponding to the potable water ingestion pathway. The program indicates whether the measured concentration (current condition) is above or below the acceptable hazard and risk levels (pass/fail).

- **Cleanup levels for soil and potable groundwater**: The Workbook provides the tools necessary to calculate protective soil and groundwater concentrations under both Methods B and Method C[2]. The Workbook "back-calculates" a protective concentration based on the target noncancer HQ of 1, and an excess risk of one in a million (1×10^{-6} or 1E-06)[3] under Method B, and one in one hundred thousand (1×10^{-5} or 1E-05) under Method C. For soil, the Workbook calculates a protective concentration for the direct contact pathway, the leaching pathway (protection of groundwater), and the vapor pathway (protection of air quality). For groundwater, the Workbook calculates a protective concentration for the potable water ingestion pathway. This calculated cleanup level might be lower or higher than the concentration measured in the sample.

The MTCASGL Workbook consists of two worksheets – the Worksheet for Calculating Soil Cleanup Levels (see Chapter 2) and the Worksheet for Calculating Potable Groundwater Cleanup Levels (see Chapter 3).

For the calculation of **soil cleanup levels**, the Workbook provides tools for evaluating the direct contact pathway, the leaching pathway (protection of groundwater), and the vapor pathway (protection of air quality).

- For the evaluation of the **direct contact pathway**, the Workbook uses the equations provided in the regulation. The Workbook allows the user to evaluate the soil ingestion pathway alone or in conjunction with the dermal pathway.

[2] Method C groundwater cleanup levels based on potable water ingestion may only be used at sites qualifying under the strict conditions set forth in WAC 173-340-706(1). Contact Ecology for methods to evaluate hazardous substances in groundwater that may qualify for a Method C groundwater cleanup level in accordance with WAC 173-340-706(1)

[3] Cancer risk is expressed in terms of lifetime excess cancer risk. This concept assumes that the risk of cancer from a given chemical is in "excess" of the background risk of developing cancer. For example, a risk of 1E-06 equates to approximately one excess cancer case in a population of one million individuals due to exposure to the cancer-causing substance over a lifetime.

- For the evaluation of the **leaching pathway**, the Workbook uses the 3-phase equilibrium partitioning model described in the regulation to calculate a soil cleanup level that will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720[xiii].

- For the evaluation of the **vapor pathway**, the Workbook provides informational tools for calculating air cleanup levels and soil concentrations that will not cause an exceedance of the air cleanup level established under WAC 173-340-750[xiv].

NOTE: The tools for evaluating the vapor pathway are provided for informational purposes only. Please consult the regulation and the site manager for more information regarding whether the pathway must be evaluated and how the pathway may be evaluated. For additional information on evaluating the vapor pathway for individual volatile hazardous substances, please see our 2022 guidance titled: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action, Publication No. 09-09-047*[vi].

For the calculation of **groundwater cleanup levels**, the Workbook provides tools for calculating only potable groundwater cleanup levels, as defined in the regulation.

When establishing cleanup levels for hazardous substances at a site, the site manager often asks **two types of questions**.

- Is the measured (or current) concentration at the site protective?

- If not, what is the protective concentration?

The Workbook allows the user to answer both of these questions for an individual hazardous substance. The Workbook provides the tools to calculate the noncancer hazard quotient (HQ) or cancer risk (risk) under current site conditions (forward calculation), and to calculate protective concentrations (backward calculation) if the measured concentration at the site is not protective. In the first instance, the Workbook requires the user to enter a measured soil or groundwater concentration for an individual hazardous substance at the site. The Workbook then executes a "forward" calculation using the equations in the regulation and solving for the noncancer HQ or risk. In the second instance, the Workbook "back-calculates" a protective concentration based on the target HQ and risk level set forth in the regulation. Also, the Workbook provides printing and previewing capabilities for all input and output screens.

The MTCASGL User's Guide describes the capabilities and limitations of the Workbook and provides step-by-step instructions for installing and using the Workbook.

This User's Guide is provided to document the methods used by Ecology to develop concentrations that meet the acceptable noncancer hazard and risk levels required by the

MTCA Cleanup Regulation, Chapter 173-340 WAC[xi]. Noncancer hazard and risk levels are described in WAC 173-340-705[xv] (Method B) and WAC 173-340-706[xvi] (Method C).

1.2 Getting started

1.2.1 File download

The MTCASGL 12.0 calculations are performed in a single Excel workbook, the "Workbook", which can be downloaded from Ecology's Tools for cleaning up contaminated sites[xvii] webpage.

1.2.2 Hardware and software requirements to run the workbook

Recommended software needed to run the Workbook and associated functions is Excel version 2003 (or later) for Windows. The software is implemented as an Excel Workbook, programmed in Visual Basic and Visual Basic for Applications (VBA), and requires Excel. The Workbook uses automatic procedures programmed in Visual Basic. However, it should not be necessary to have Visual Basic installed on your system to operate the Workbook.

1.2.3 Installing the workbook

This section provides instructions for installing and opening the Workbook file.

Download the Excel Workbook from our "Tools for cleaning up contaminated sites" webpage to your hard drive. Prior to opening up the Workbook, make sure that Macros are enabled in Excel (see below).

Enable Macros using the steps below.

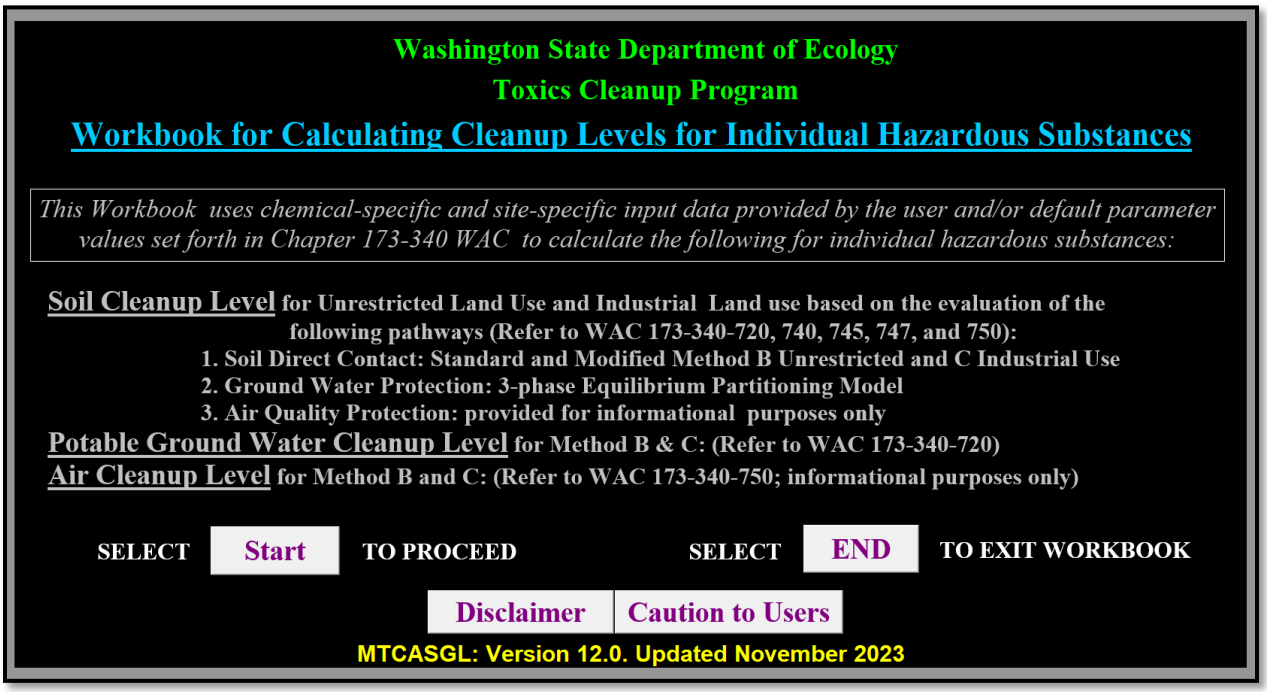
1. In Excel, go to **File > Options**.
2. Click **Trust Center**, and then click **Trust Center Settings**.
3. In the Trust Center, click **Macro Settings**.
4. Under Macro Settings, click **Enable VBA macros**.

Note: Do not attempt to run the Workbook without saving the file to your hard drive. It may cause error messages, or the Workbook may not run properly. It is important to use the END button when closing the file. And it is good practice to save working files under a new name.

1.2.4 Assessing the worksheet and opening the title screen

Once the Workbook is successfully opened and loaded into Excel, the title sheet will appear. Be sure that MACROs are enabled (see Section 1.2.3). To use the Workbook, click on the START button (to exit, click on the END button). It is important to use the END button to exit the Workbook, so your previous default Excel settings (toolbars, work-area format) are restored. By opening the *MTCASGL_v12.0.xls* file, you will view **Figure 1-1**. At this point, you should see the following title screen as it appears below:

Figure 1-1: Opening Title Screen of MTCASGL



1.2.5 Saving and closing the workbook

→ **USE THE END BUTTON** ←

Once an analysis is complete, it is good practice to print out a copy of the entire Workbook as a record. At this point, you may also wish to save the Workbook under a new name [FILE – SAVE AS]. If you accidentally exit without using the END button, you can re-establish your toolbars by clicking on [VIEW] and selecting the toolbars you wish to use. You may also need to click on [FILE-OPTIONS] and make selections as appropriate to re-establish certain work area components.

When you click on the END button, you will be prompted to save your work, and you can do so by answering [yes] and saving the file under a new file name. Otherwise, answer [no] and you will exit the Workbook without saving any changes.

Note: The Workbook should be closed (exited) using the END button at the top of the sheet. Do not close the Workbook using the typical means provided in Excel (i.e., [FILE-CLOSE] or clicking on the "X"). Using the END button allows the programmed routines in the Workbook to return the Excel toolbar displays and other format options to those you normally use.

1.3 Potential error messages and troubleshooting/ operating tips

"# # # #" is displayed in a number box: Display properties chosen by users are not compatible with the cell format originally designed for the value (e.g., the number is too big to fit into the cell window). To fix this problem, select the cell, click on "Home" tab and then the "Format" group, click on "Format Cells" and then select the "Number" category. Change either the format, length of column, or the font size of the cell until the value is visible.

"# DIV/0!" or "#NAME?" is displayed in a box: The most common cause of this problem is that some input data are missing. Double-check to make certain that all of the input cells required for your run have data in them.

The buttons won't work: Click on another cell or hit the enter/return key, and then click the buttons and they should work.

Text labels appear to be cut off: On some monitor resolutions in Microsoft Windows, some cell labels may appear cut off. This should affect only the screen display, and in most cases, printouts should not be affected.

Other potential error messages and opening more than one Workbook at a time: It is possible that you may receive other error messages when trying to open the Workbook. Be sure the MACROs are enabled to use the tools properly (see Section 1.2.3). Some error messages may require you to refer to online help or the documentation of the host application. Check with your network operator or information technology specialist to be sure your Excel application can accept MACROs operation and to address other host application-related errors. It is not advisable to load and use more than one copy of the Workbook at the same time. It may cause it to function improperly.

Preview, printout (reporting features) and readability of worksheet: The Workbook provides printing and reviewing capabilities for all input/output screens. To view the printable worksheet, click on the "Preview" button at the top of any worksheet. Each worksheet can be printed by selecting the appropriate "Print" button. The same print options are available on the "Main Menu." Some users may have difficulty viewing worksheet numbers or text. To enlarge

your view of a particular sheet, click on "View" in the main toolbar and select "Zoom." Choose a magnification that works best for your needs and save it as modified.

Input/output worksheet prints on one page for most computer/printer configurations. The worksheet is designed at "1024 x 768" pixel screen resolution, making it more readable on new computer configurations. For older systems with lower resolution, simply changing the screen "zoom" level to a higher percent (or more) instead of lower percent will improve readability.

Restoring Excel tool bars and miscellaneous options: To maximize screen area on the computer to view the data, most of the typical Excel toolbars are turned off when the Workbook is loaded. However, if you prefer to have these toolbars available, you can restore them by hitting the "Escape" button on your keyboard. To restore the "Formula" bar along with standard Excel row and column labels, select "Formula Bar" and "Headings" within the "View" tab. You can also resize the pages using the "Zoom" feature in the "View" tab to make the tables and text larger or smaller.

1.4 Restrictions and caution on use of the workbook

The requirements and procedures for establishing cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation, Chapter 173-340 WAC[xi]. The use of the MTCASGL User's Guide and the associated Workbook may not be sufficient to establish cleanup levels under the regulation. The Workbook is merely a computational tool and does not provide all the information necessary to establish cleanup levels for a site. Appropriate background, training, and experience are necessary to accurately use the Workbook. Some available resources include guidance provided on our CLARC webpage[xii] and training via our MTCA 101 class[4].

Restrictions and cautions related to calculating soil and potable groundwater cleanup levels are discussed below

1.4.1 Calculating soil cleanup levels

The **soil cleanup levels** calculated using the soil worksheet accounts for the following:

- Concentrations based on protection of human health (direct contact pathway)
- Concentrations based on protection of groundwater (leaching pathway)

[4] MTCA 101: Understanding and Applying Washington State's Model Toxics Control Act (hosted by the National Environmental Management Academy (NEMA) – check the training calendar for availability @ https://nemallc.com).

- Concentrations based on protection of air (vapor pathway – informational only[5])
- Natural background concentrations
- Practical quantitation limits (PQLs)

The **soil cleanup levels** calculated using the Workbook **DO NOT** account for the following:

- Concentrations established under applicable state and federal laws
- Concentrations based on protection of terrestrial ecological receptors
- Residual saturation limit for protection of groundwater
- Total site noncancer hazard and risk

The soil cleanup levels calculated using the Workbook might need to be manually adjusted to account for these considerations (see WAC 173-340-740(5)[xviii] and WAC 173-340-745(6))[xix].

1.4.2 Calculating potable groundwater cleanup levels

The potable groundwater cleanup levels calculated using the groundwater worksheet accounts for the following:

- Concentrations established under applicable state and federal laws
- Concentrations based on protection of human health
- Natural background concentrations
- PQLs

The **potable groundwater cleanup levels** calculated using the groundwater worksheet **DO NOT** account for the following:

- Concentrations based on protection of air quality (vapor pathway)
- Concentrations based on potential surface water impacts
- Nonaqueous phase liquid (NAPL) limitation[6]

[5] To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action, Publication No.09-09-047* at https://apps.ecology.wa.gov/publications/SummaryPages/0909047.html

[6] The cleanup level determined in WAC 173-340-720 shall not exceed a concentration that would result in NAPL being present in or on the groundwater. See WAC 173-340-720(7)(d).

- Total site noncancer hazard and risk

The groundwater cleanup levels calculated using the Workbook might need to be manually adjusted to account for these considerations (see WAC 173-340-720(7)[xiii]).

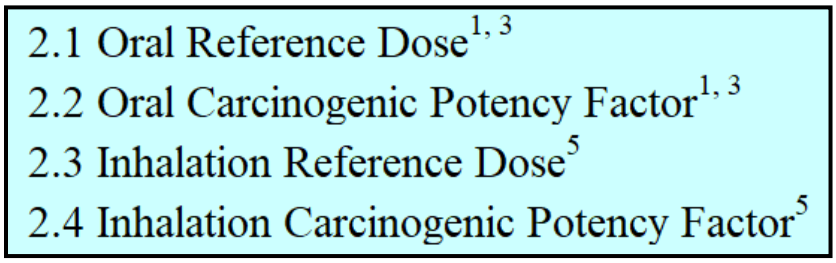
1.5 What's new in MTCASGL Workbook Version 12.0?

MTCASGL was updated in 2023 to **remove** the Henry's law conversion tool that allowed the user to enter the constant in units of atm-m^3/mol to determine the unitless form at 13° Celsius. Rather, the user may use the dimensionless Henry's law at 13° Celsius provided in Ecology's CLARC[xii] data tables. The CLARC data tables were updated in 2021 to include chemical-specific parameters for more chemicals including Henry's law at 25° and 13° Celsius. Data from the Oak Ridge National Laboratory (ORNL) Risk Assessment Information System (RAIS)[xx] chemical database (i.e., boiling point, critical temperature, enthalpy of vaporization) along with formulas in EPA's Vapor Intrusion Screening Level (VISL) Calculator[xxi] were used to adjust Henry's law based on 25° Celsius to 13° Celsius. See updated instructions in Section 2.3.4 for inputting **Henry's Law Constant**.

The MTCASGL Workbook Version 12.0 still retains the minor modifications made in 2006 to enhance the usability of the program (see below).

- Footnotes are inserted for input parameters to indicate which exposure pathway evaluations these inputs are used for. See **Figure 1-2**.

Figure 1-2: Examples of Footnotes



Footnotes:

1 Soil ingestion only

3 Soil to groundwater (leaching pathway)

5 Soil to air (vapor pathway)

- Codes are revised to reduce memory requirements, file size and simulation time and to increase calculation efficiency.

Chapter 2. Chapter 2: Calculating Soil Cleanup Levels

The **Worksheet for Calculating Soil Cleanup Levels** (soil worksheet) provides tools for evaluating the direct contact, soil leaching, and vapor pathways. The worksheet calculates a Method B or Method C soil cleanup level[7].

- For evaluation of the **direct contact pathway**, the worksheet uses the equations provided in the regulation (see Appendix A). The worksheet allows the user to evaluate the soil ingestion pathway alone or in conjunction with the dermal pathway.
- For evaluation of the **leaching pathway**, the worksheet uses the 3-phase equilibrium partitioning model described in the regulation (see Appendix B) to calculate a soil cleanup level that will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720[xiii].
- For evaluation of the **vapor pathway**, the worksheet uses the equations provided in the regulation to calculate an air cleanup level (see Appendix C) and then calculates a soil cleanup level that will not cause an exceedance of that air cleanup level using the 3-phase equilibrium partitioning model and the site-specific vapor attenuation factor entered by the user.

NOTE: The tools for evaluating the vapor pathway are provided for informational purposes only. Please consult the regulation and the site manager for more information regarding whether the pathway must be evaluated and how the pathway may be evaluated. For additional information on evaluating the vapor pathway for individual volatile hazardous substances, please see our 2022 guidance titled: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action, Publication No. 09-09-047*[vi].

2.1 Accessing the soil worksheet

Once the MTCASGL Workbook is successfully loaded into Excel, the title sheet will appear as shown prior in **Figure 1-1**. Be sure to enable Excel MACROs prior to opening up the Workbook (see Section 1.2.3). To use the Workbook tool, click on the START button (to exit, click on the END button). It is important to use the END button to exit the Workbook, so your previous default Excel settings (toolbars, work-area format) are restored. Selecting the START button makes the soil worksheet appear on your screen (light blue background).

[7] Important, see cautions for use of the soil worksheet in Section 1.4.1.

Note the following regarding the structure and contents of the soil worksheet.

- Non-colored (white) cells in the sheet are used for data entry (other cells in the Workbook are locked and cannot be modified).
- The worksheet is divided into Sections A and B – Section A is the upper portion of the worksheet and allows users to input data. Section B is the bottom portion of the worksheet and contains the "Summary of Soil Cleanup Level Calculations".

2.2 Equations and parameters

The soil worksheet provides tools for evaluating the direct contact pathway, the leaching pathway (protection of groundwater), and the vapor pathway (protection of air quality).

2.2.1 Direct contact pathway

For the evaluation of the direct contact pathway, the worksheet uses the standard equations provided in the regulation (see Appendix A). The worksheet allows the user to evaluate the soil ingestion pathway alone or in conjunction with the dermal pathway.

For each of the parameters used in the equations, default assumptions (values) are set forth in the regulation to calculate **standard** Method B or C cleanup levels. Under **modified** Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The regulation specifically describes which parameters may be adjusted and how they may be adjusted.

- **IF** the regulation does not allow a parameter to be adjusted, **THEN** the worksheet uses the default value for that parameter provided in the regulation. Also, the parameter is not listed in the worksheet and the user may not input data for that parameter.
- **IF** the regulation allows a parameter to be adjusted (e.g., gastrointestinal absorption fraction), **THEN** the parameter is listed in the worksheet and the user may input either the default value provided in the regulation or a site-specific or chemical-specific value derived under the regulation.

2.2.2 Leaching pathway

For the evaluation of the leaching pathway, the worksheet uses the 3-phase equilibrium partitioning model described in the regulation (see Appendix B) to calculate a cleanup level that will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720[xiii]. For each of the parameters used in the equations, the user may input either the

default value provided in the regulation, or a site-specific or chemical-specific value derived under the regulation.

For the evaluation of the leaching pathway, the worksheet also checks for soil saturation limits and warns the user if the soil saturation condition is exceeded.

2.2.3 Vapor pathway

For the evaluation of the vapor pathway, the worksheet **first** uses the standard equations provided in the regulation (see Appendix C) to calculate air cleanup levels. For each of the parameters used in the equations, default assumptions (values) are set forth in the regulation to calculate **standard** Method B or C cleanup levels. Under **modified** Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The regulation specifically describes which parameters may be adjusted and how they may be adjusted.

- **IF** the regulation does not allow a parameter to be adjusted, **THEN** the worksheet uses the default value for that parameter provided in the regulation. Also, the parameter is not listed in the worksheet and the user may not input data for that parameter.
- **IF** the regulation allows a parameter to be adjusted (e.g., the inhalation absorption fraction), **THEN** the parameter is listed in the worksheet and the user may input either the default value provided in the regulation or a site-specific or chemical-specific value derived under the regulation.

Second, the worksheet converts the calculated air cleanup level into a soil vapor concentration using the vapor attenuation factor entered by the user.

Third, the worksheet uses the 3-phase equilibrium partitioning model (see Appendix B) and the soil vapor concentration to calculate the associated soil concentration – the concentration that is protective of air quality at the exposure point (point of compliance).

NOTE: The tools for evaluating the vapor pathway are provided for informational purposes only. Please consult the regulation and the site manager for more information regarding whether the pathway must be evaluated and how the pathway may be evaluated. For additional information on evaluating the vapor pathway for individual volatile hazardous substances, please see our 2022 guidance titled: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action, Publication No. 09-09-047*[vi].

2.3 Entering data for input parameters

As discussed above, the worksheet lists only those parameters that may be adjusted by the user. For each of the parameters listed in the worksheet, the user must either enter the default

value provided in the regulation or a site-specific or chemical-specific value derived under the regulation.

NOTE: If no data is available for an input parameter, then leave the input box blank unless specified otherwise.

As illustrated in the following sections, the parameters for which the user must enter data are listed on the left side of the worksheet. The user must enter the data in the corresponding non-shaded (white) boxes on the right side of the worksheet.

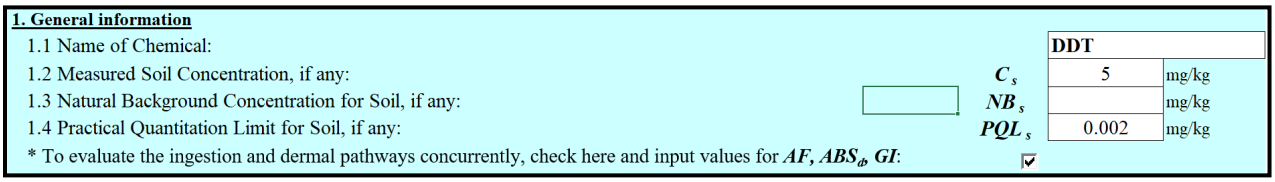
Section A of the worksheet is organized into **seven parts**. Each of the parameters listed under those parts is listed and described below. For each parameter, this User's Guide lists the default value provided in the regulation and references the applicable procedures for deriving a site-specific or chemical-specific value under the regulation.

Header Information: In the rectangular box at the top of the soil worksheet, enter the date, site name, and evaluator name. **NOTE:** Once an evaluation has been completed for a particular site, it is good practice to print out the results. Click on the Preview or Print button to confirm that the proper header information appears on all printout sheets. Remember to change the header information EACH TIME a new set of data is entered.

2.3.1 Input data – Part 1: General Information

The first part of the worksheet (see **Figure 2-1**) requires the user to input the following general information.

Figure 2-1: General Information



Name of chemical: Enter the name of the chemical to be evaluated.

Measured soil concentration (if known): This parameter is used to calculate the carcinogenic risk and noncarcinogenic HQ at the site under current conditions. Enter the soil concentration in milligrams per kilogram of soil (dry weight basis).

Natural background (NB_s) soil concentration (if known): This parameter is used to adjust the soil cleanup level, if necessary. Methods for defining natural background concentrations are provided in WAC 173-340-709[xxii]. Ecology has published information on background levels of

certain metals (*Natural Background Soil Metals Concentrations in Washington State, Publication No. 94-115*[xxiii]). Also, Ecology has adopted a natural background soil level of 5.2 nanograms/kilogram (ng/kg) for dioxin and furan mixtures. The chemical concentrations of the dioxin and furan mixture in soil are converted to a 2,3,7,8-TCDD total toxicity equivalence (TEQ) concentration which may then be compared to the background soil level of 5.2 ng/kg[8].

Practical quantitation limit (*PQL$_s$*) for soil (if known): This parameter is used to adjust the soil cleanup level, if necessary. The ***PQL$_s$*** is the lowest concentration of the contaminant that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using department approved methods. The analytical laboratory or site manager can assist in identifying the appropriate ***PQL$_s$***.

Checkbox – Is an evaluation of the dermal pathway required? The checkbox item at the bottom of the first part of the worksheet requires the user to indicate whether an evaluation of the dermal pathway is required to calculate a soil concentration that is protective of human health based on direct contact. To determine whether an evaluation of the dermal pathway is required, see WAC 173-340-740[xviii](3)(c)(iii) and WAC 173-340-745[xix](5)(c)(iii). If an evaluation of the dermal pathway is required, then the user must enter a check in the checkbox and enter values for the following exposure parameters in Section 2.3.3 Input Data – Part 3: Exposure Parameters.

- Adherence Factor (***AF***)
- Dermal absorption fraction (***ABS$_d$***)
- Gastrointestinal Absorption Conversion Factor (***GI***)

2.3.2 Input data – Part 2: Toxicological properties of the chemical

The second part of the worksheet (see **Figure 2-2**) requires the user to input the following chemical-specific toxicological data.

Figure 2-2: Toxicological Properties

2. Toxicological Properties of the Chemical: Chemical-Specific			
2.1 Oral Reference Dose[1, 3]	RfD_o	0.0005	mg/kg-day
2.2 Oral Carcinogenic Potency Factor[1, 3]	CPF_o	0.34	kg-day/mg
2.3 Inhalation Reference Dose[5]	RfD_i		mg/kg-day
2.4 Inhalation Carcinogenic Potency Factor[5]	CPF_i	0.34	kg-day/mg

[8] Ecology, 2010. Technical Memorandum #8: Natural Background for Dioxins/Furans in WA Soils. https://apps.ecology.wa.gov/publications/SummaryPages/1009053.html

Oral reference dose (RfD_o): Enter the oral reference dose (mg/kg-day) for chemicals having noncarcinogenic toxicity. The applicable oral reference dose for a chemical is published in CLARC[xii]. Note that an oral reference dose may not be available for some chemicals. The process for establishing a reference dose is defined in WAC 173-340-708[xxiv](7).

Oral carcinogenic potency factor (CPF_o): Enter the oral carcinogenic potency factor (kg-day/mg) for chemicals having carcinogenic toxicity. The applicable oral cancer potency factor for a chemical is published in CLARC. Note that an oral cancer potency factor may not be available for some chemicals. The process for establishing a cancer potency factor is defined in WAC 173-340-708(8).

Inhalation reference dose (RfD_i): Enter the inhalation reference dose (mg/kg-day) for chemicals having noncarcinogenic toxicity. The applicable inhalation reference dose for a chemical is published in CLARC. Note that an inhalation reference dose may not be available for some chemicals. The process for establishing a reference dose is defined in WAC 173-340-708(7).

Inhalation carcinogenic potency factor (CPF_i): Enter the inhalation carcinogenic potency factor (kg-day/mg) for chemicals having carcinogenic toxicity. The applicable inhalation cancer potency factor for a chemical is published in CLARC. Note that an inhalation cancer potency factor may not be available for some chemicals. The process for establishing a cancer potency factor is defined in WAC 173-340-708(8).

2.3.3 Input data – Part 3: Exposure parameters

The third part of the worksheet (see **Figure 2-3**) requires the user to input data for the following exposure parameters.

Figure 2-3: Exposure Parameters

3. Exposure Parameters			
3.1 Inhalation Correction Factor (default = "2" for volatiles; "1" for all others)[4]	*INH*	1	unitless
3.2 Inhalation Absorption Fraction (default = "1")[5]	ABS_i	1	unitless
3.3 Gastrointestinal Absorption Fraction (default = "1")[1, 2]	*AB1*	1	unitless
3.4 Adherence Factor (default = "0.2")[2]	*AF*	0.2	mg/cm^2-day
3.5 Dermal Absorption Fraction (chemical-specific or defaults)[2]	ABS_d	0.1	unitless
3.6 Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults)[2]	*GI*	0.5	unitless

Inhalation correction factor (INH): This parameter is used to calculate the groundwater cleanup level and accounts for potential exposure to volatile contaminants via non-ingestion groundwater water use (e.g., showering). Enter the applicable default value "2.0" for volatile organic compounds (as defined in WAC 173-340-200[xxv]) and "1.0" for all other chemicals or enter a chemical-specific value established under WAC 173-340-720[xiii](4)(c)(i). The applicable default value for this parameter is published in CLARC.

Inhalation absorption fraction (*ABS_i*): This parameter is used to calculate the air cleanup level. Enter the default value of "1.0" or enter a chemical-specific value established under WAC 173-340-750[xiv](3)(c)(i).

Gastrointestinal absorption fraction (*AB1*): This parameter is used to calculate a soil concentration that is protective of human health based on direct contact via incidental ingestion. Enter the default value of "1.0" or enter a chemical-specific value established under WAC 173-340-740[xviii](3)(c)(ii)(B) or WAC 173-340-745[xix](5)(c)(ii)(B). The applicable default value for this parameter is published in CLARC[xii].

Adherence factor (*AF*): This parameter is used to calculate a soil concentration that is protective of human health based on direct contact. The parameter is specifically used to evaluate dermal contact. Enter the default value of "0.2" or enter a chemical-specific value established under WAC 173-340-740(3)(c)(ii)(C) or WAC 173-340-745(5)(c)(ii)(C). If an evaluation of the dermal pathway is not required, then leave this input box blank.

Dermal absorption fraction (*ABS_d*): This parameter is used to calculate a soil concentration that is protective of human health based on direct contact. The parameter is specifically used to evaluate dermal contact. The parameter is chemical-specific. Enter a chemical-specific value established under WAC 173-340-740(3)(c)(ii)(C) or 173-340-745(5)(c)(ii)(C) or enter the applicable default value listed below.

- "0.01" for inorganic hazardous substances.
- "0.0005" for volatile organic compounds with a vapor pressure ≥ benzene.
- "0.03" for volatile organic compounds with a vapor pressure < benzene.
- "0.1" for other organic hazardous substances.

NOTE: Vapor pressure of Benzene is 0.125 atm (or, 95 mm Hg, 95 torr, 12.7 kPa) at 25°C.

The applicable default value for this parameter is published in CLARC. If an evaluation of the dermal pathway is not required, then leave this input box blank.

Gastrointestinal Absorption Conversion Factor (*GI*): This parameter is used to derive a **dermal** reference dose based on the oral reference dose or a **dermal** cancer potency factor based on the oral cancer potency factor. The dermal toxicity index is derived by dividing or multiplying the oral index by GI (as shown below).

$$RfD_d = RfD_o \times GI \quad or \quad CPF_d = CPF_o \div GI$$

This parameter is chemical-specific. Enter a chemical-specific value established under WAC 173-340-740[xviii](3)(c)(ii)(C) or WAC 173-340-745[xix](5)(c)(ii)(C) or enter the applicable default value listed below.

- "0.2" for inorganic hazardous substances
- "0.8" for volatile organic compounds
- "0.5" for other organic hazardous substances

The applicable default value for this parameter is published in CLARC[xii]**Error! Bookmark not defined.**. If an evaluation of the dermal pathway is not required, then leave the input box blank.

2.3.4 Input data – Part 4: Physical and chemical properties of the chemical

The fourth part of the worksheet (see **Figure 2-4**) requires the user to input chemical-specific data for the following physical and chemical properties of the chemical:

Figure 2-4: Physical and Chemical Properties

4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	6.779E+05	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway*	H_{cc}	1.277E-04	unitless
**Enter the dimensionless Henry's law constant at 13 deg Celsius if available in CLARC. Otherwise enter the value at 25 deg Celsius if availabe in CLARC. CLARC = Ecology Cleanup Levels and Risk Calculations Database*			
Solubility of the Chemical in Water: for the calculation of soil saturation limit	S	5.500E-03	mg/l

Soil organic carbon-water partitioning coefficient (K_{oc}): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is chemical-specific.

- For **organic hazardous substances**, enter the K_{oc} value. The Workbook calculates a value for the distribution coefficient (K_d) using the K_{oc} value entered here, and the soil fraction of organic carbon (f_{oc}) value entered in the sixth part of the worksheet using MTCA Equation 747-2 (shown in Attachment B): $K_d = K_{oc} \times f_{oc}$. Applicable default values for these parameters (i.e., K_{oc} and K_d) are published in CLARC. Methods to derive a site-specific K_d value, which includes the K_d equation above for organic chemicals, are detailed in WAC 173-340-747[xxviii](5)(b).
- For metals, enter the K_d instead of the K_{oc} value here and enter "1.0" for the f_{oc} value in the sixth part of the worksheet. Applicable default values for K_d are published in CLARC. Methods to derive a site-specific K_d value are detailed in WAC 173-340-747(5)(b).

Henry's law constant (H_{cc}): The dimensionless (i.e., H_{cc}) form of Henry's law is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is chemical-specific.

- For metals except mercury, enter the default value of "0".
- For mercury, enter the default value of "0.47" or enter a value derived from the scientific literature, provided the requirements in WAC 173-340-702[xxvi](14), (15) and (16) are met.

To enter Henry's law constant, follow the set of instructions below.

- For default calculation of soil cleanup levels to protect groundwater, Henry's law constants at 13° Celsius should be used. Enter the dimensionless form of Henry's law at 13° Celsius in the "H_{cc} [ ] unitless" box. If chemical-specific data is not available to derive a Henry's law constant at 13° Celsius, the Henry's law constant at 25° Celsius may be used in the calculation, if available. If a Henry's law value is not available, a value of zero may be conservatively used to make the calculation. It's noted that chemical loss due to volatilization based on Henry's law is not a major driver in the 3-phase partitioning model.

  Applicable default values for Henry's law at 25° and 13° Celsius are published in CLARC[xii].

- For individual organic hazardous substances in which a Henry's law value is not available in CLARC, enter a value derived from the scientific literature, provided the requirements in WAC 173-340-702(14), (15) and (16) are met. In this circumstance, the user may opt to use the slightly more conservative dimensionless Henry's law at 25° Celsius in lieu of trying to adjust it to 13° Celsius.

- A Henry's law constant provided in units of **atm-m^3/mol** may be converted to the dimensionless form using the following equation:

$$Hcc = Henry's\ law\ (atm\text{-}m^3/mol) \div (R \times T)$$

Where:

R = Ideal gas constant (8.20575 x 10^{-5} atm-m^3/mol-K)

T = Temperature in Kelvins (25° Celsius = 298.15 K; 13° Celsius = 286.15 K)

Notes:

1. The value of (R x T) at 25° Celsius is 0.02446; and 0.02348 at 13° Celsius.

2. The equation may be simplified as:

   H_{cc} at 25° Celsius = Henry's law at 25° Celsius (atm-m^3/mol) ÷ 0.02446

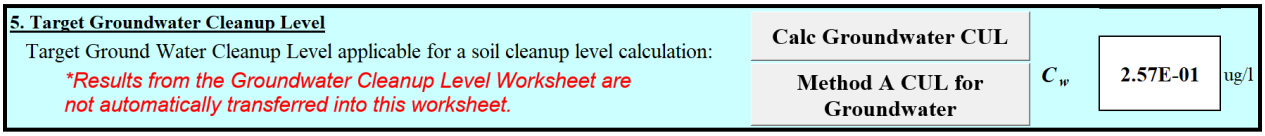
   H_{cc} at 13° Celsius = Henry's law at 13° Celsius (atm-m^3/mol) ÷ 0.02348

Aqueous solubility (*S*): This parameter is used to calculate the soil saturation limit (C_{sat}). This soil saturation limit corresponds to the theoretical chemical concentration in soil at which sorption limits of the soil particles, solubility limits of the soil pore water, and saturation of soil pore air have all been reached. The parameter is chemical-specific. The aqueous solubility of the contaminant must be entered as milligrams of contaminant per liter of water (mg/L). Information on solubility for common contaminants can be obtained from the scientific literature. These literature values may be used, provided the requirements in WAC 173-340-702[xxvi](14), (15) and (16) are met. The applicable default value for this parameter is published in CLARC[xii]**Error! Bookmark not defined.**.

2.3.5 Input data – Part 5: Target groundwater cleanup level

The fifth part of the worksheet (see **Figure 2-5**) requires the user to input the target groundwater cleanup level for the site[9]. The target groundwater cleanup level is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the target groundwater cleanup level). The parameter is site- and chemical-specific.

Figure 2-5: Target Groundwater Cleanup Level



The Workbook provides two methods for calculating the target groundwater cleanup level. These two methods are described below.

Use and adjustment of Method A values in MTCA Table 720-1: For chemicals listed in WAC 173-340-900[xxvii], Table 720-1 except petroleum mixtures, the value listed in Table 720-1 for a

[9] The user must develop a target groundwater cleanup level based on the exposure pathway (e.g., potable water ingestion, protection of surface water, etc.) that generates the most stringent cleanup level (i.e., lowest concentration).

chemical may be used as the target groundwater cleanup level[10], provided the value is manually adjusted based on the following:

- Consideration of potential surface water impacts (see WAC 173-340-720[xiii](4)(b)(ii) and WAC 173-340-720(5)(b)(ii))
- Consideration of the nonaqueous phase liquid (NAPL) limitation[11] (see WAC 173-340-720(7)(d))
- Consideration of total site noncancer hazard and risk (see WAC 173-340-720(7)(a))

To see the values listed in WAC 173-340-900[xxvii], Table 720-1, click the Method A CUL for Groundwater button to activate a "pop-up" list. The value from Table 720-1 must be manually adjusted as described above and then manually entered in the soil worksheet.

WARNING: The Workbook **DOES NOT** automatically enter a value from WAC 173-340-900, Table 720-1 in the soil worksheet.

Calculation of Method B or Method C value: For cleanups performed under Method B (WAC 173-340-705[xv]) or C (WAC 173-340-706[xvi]), the user may calculate a potable groundwater cleanup level using the groundwater worksheet within the Workbook. Alternatively, the user may use the pre-calculated Method B or C potable groundwater levels in CLARC[xii]**Error! Bookmark not defined.** based on standard default exposure assumptions. If there is insufficient data (e.g., lack of toxicity data) to calculate a Method B or C potable groundwater value, or if a Method A value has been adjusted based on natural background (e.g., arsenic in groundwater), the user may default to the Method A potable groundwater level in WAC 173-340-900, Table 720-1 if one is available[12]. To access the worksheet, click on the **Calc Groundwater CUL** button. See Section 2.2 for instructions on calculating a potable groundwater cleanup level.

Before calculating the potable groundwater cleanup level (before clicking on the button), values for the following parameters must be entered in the soil worksheet.

[10] For qualifying cleanups performed under Method A (WAC 173-340-704), all of the indicator hazardous substances at the site should have a Method A standard. See Ecology's Guidance on the Use of Method A, B, and C Cleanup Levels and Mixing Methods at https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/MixingMethodsABC.pdf

[11] The cleanup level determined in WAC 173-340-720 shall not exceed a concentration that would result in NAPL being present in or on the groundwater. See WAC 173-340-720(7)(d).

[12] Examples of when it is appropriate to use a Method A level at a Method B or C site are provided in Ecology's Guidance on the Use of Method A, B, and C Cleanup Levels and Mixing Methods. https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/MixingMethodsABC.pdf

- Oral Reference Dose (***RfD$_o$***) – Part 2.
- Oral Carcinogenic Potency Factor (***CPF$_o$***) – Part 2.
- Inhalation Correction Factor (**INH**) – Part 3.

The Workbook calculates a potable groundwater cleanup level based on the values entered for these parameters and the parameters listed in the groundwater worksheet. The potable groundwater cleanup level calculated using the groundwater worksheet[13] must be manually adjusted (as described in Section 3.5) and then manually entered in the soil worksheet (as noted in Section 3.6).

WARNING: The Workbook **DOES NOT** automatically enter the result from the groundwater worksheet.

2.3.6 Input data – Part 6: Hydrogeological characteristics of the site

The sixth part of the worksheet (see **Figure 2-6**) requires the user to input default or site-specific data for the following hydrogeological characteristics of the site:

Figure 2-6: Site-specific Hydrological Information

6. Site-Specific Hydrogeological Characteristics			
Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.3	unitless
Volumetric Air Content (default = "0.13"):	Θ_a	0.13	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.001	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	DF	20	unitless

Total soil porosity (n): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. Enter the default value of "0.43" or enter a site-specific value determined under WAC 173-340-747[xxviii](6)(d)(iii)(D) using site-specific measurements. The site-specific soil porosity may be calculated using the following equation:

$$n = 1 - \frac{\rho_b}{\rho_s}$$

[13] The Method B or C potable groundwater level within the groundwater worksheet also accounts for user inputted applicable state or federal laws, the PQL, and natural background levels.

Table 2-1: Porosity and Density Information

Parameter	Definition	Default Value	Units
n	Total soil porosity	Calculated	unitless
ρ_b	Dry soil bulk density	1.5 **(1)**	kg/L
ρ_s	Soil particle specific gravity	2.65 **(2)**	kg/L

Notes:

(1) Use the default value of 1.5 kg/L or use a site-specific value derived under WAC 173-340-747[xxviii](5)(c). Use the same value as entered in Part 6 of the worksheet.

(2) Use the default value of 2.65 kg/L or use a site-specific value derived under WAC 173-340-747 (6)(d)(iii)(D). A site-specific value may be derived by measuring the soil particle specific gravity using ASTM Method D854-00.

Note that the sum of the volumetric water content and the volumetric air content must equal the total soil porosity.

Volumetric water content (θ_w): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. Enter the default value of "0.30" or enter a site-specific value derived under WAC 173-340-747(5)(d) using site-specific measurements. Note that the sum of the volumetric water content and the volumetric air content must equal the total soil porosity.

Volumetric air content (θ_a): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. The value for volumetric air content CANNOT be entered. The Workbook automatically calculates a value based on the values entered for total soil porosity (n) and volumetric water content (θ_a) using the equation below.

$$\theta_a = n - \theta_w$$

If the default values for total soil porosity (n = 0.43) and volumetric water content (θ_w = 0.3) are entered, then the "default" volumetric air content is 0.13.

Dry soil bulk density (ρ_b): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. Enter the default value of "1.5" or enter a site-specific value derived under WAC 173-340-747(5)(c) using site-specific measurements.

Fraction soil organic carbon (f_{oc}): The fraction of soil organic carbon is the total mass of organic carbon divided by a unit mass of soil (mass of carbon/mass of soil). This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific.

- For **organic hazardous substances**, enter the default value of "0.001" or enter a site-specific value derived under WAC 173-340-747[xxviii](5)(b)(i). The Workbook calculates a value for K_d using the f_{oc} value entered here and the K_{oc} value entered in the fourth part of the worksheet using Equation 747-2: $K_d = K_{oc} \times f_{oc}$.

- For **metals**, enter "1" for the f_{oc} value here and enter the distribution coefficient (K_d) instead of the K_{oc} value in the fourth part of the worksheet.

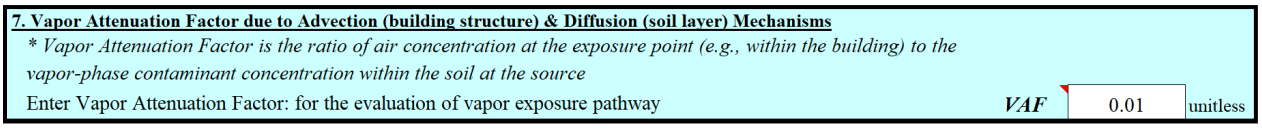
Soil samples that are analyzed for f_{oc} must be collected outside the area of contamination and below the root zone. The results are usually reported as percent organic carbon. The reported value can be converted to a fraction by dividing by 100.

Dilution factor (*DF*): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. Enter the applicable default value ("20" for unsaturated zone soil and "1" for saturated zone soil) or enter a site-specific value derived under WAC 173-340-747(5)(f) using site-specific estimates of infiltration and groundwater flow rate.

2.3.7 Input data – Part 7: Vapor attenuation factor for the site

The seventh part of the worksheet (see **Figure 2-7**) requires the user to input the vapor attenuation factor for the site.

Figure 2-7: Vapor Attenuation Factor



Vapor attenuation factor (*VAF*): This parameter is used to calculate a soil concentration that is protective of air quality (that will not cause an exceedance of the air cleanup level at the point of compliance). This parameter is site- and chemical-specific.

The worksheet uses the 3-phase equilibrium partitioning model to predict the soil vapor concentration at the source based on the measured soil concentration. The worksheet then uses the vapor attenuation factor to predict the air concentration at the point of compliance based on the soil vapor concentration at the source. The vapor attenuation factor is based on several factors, including the emission rate of the contaminant from soil (due to diffusion and

advection) and the amount of dilution that occurs through mixing with indoor and or outdoor ambient air.

WARNING: To calculate a soil cleanup level based on the vapor pathway, the user must enter a value for ***VAF***. The user must enter a **site-specific** value because a **default value has NOT been established**.

If it appears that the vapor pathway is a controlling factor at a site, the user needs to consult with the Ecology site manager to identify an appropriate method for evaluating the vapor pathway. For additional information on evaluating the vapor pathway for individual volatile hazardous substances, please see our 2022 guidance titled: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action, Publication No. 09-09-047*[vi].

THIS COMPLETES DATA ENTRY FOR THE SOIL WORKSHEET. SAVE YOUR WORK BEFORE CONTINUING.

2.4 Output – Interpreting the result

The worksheet automatically calculates protective soil concentrations for the different pathways and then calculates a soil cleanup level based on those protective concentrations and other limits.

The worksheet displays the calculation results in two tables at the bottom of the active sheet.

2.4.1 Summary of results

The first table (example shown below) displays the most stringent soil concentration based on soil direct contact and groundwater protection, as well as other limits.

The first table requires the **user** to make **two decisions** that will affect the results displayed in the table.

1. Can soil cleanup levels be established under Method C (industrial land use)?

   To determine whether soil cleanup levels can be based on industrial land use (Method C), see WAC 173-340-745[xix](1).

   - If the site qualifies for use of Method C to establish soil cleanup levels, then enter a check in the box.
   - If the site does not qualify for use of Method C to establish soil cleanup levels, then leave the checkbox blank.

2. Can air cleanup levels be established under Method C?

   To determine whether the air cleanup level can be based on industrial land use (Method C), see WAC 173-340-745[xix](1).

   - If the site qualifies for use of Method C to establish air cleanup levels, then enter a check in the box.
   - If the site does not qualify for use of Method C to establish air cleanup levels, then leave the checkbox blank.

The first table then displays the results (example shown in **Figure 2-8**). A description of the content of the table is provided below.

Figure 2-8: Calculation Summary Table

B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: DDT

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	3.491E+00	mg/kg
Natural Background concentration for Soil:	N/A	mg/kg
Practical Quantitation Limit for Soil:	0.002	mg/kg
Soil Cleanup Level (not considering vapor pathway):	3.491E+00	mg/kg
Soil concentration based on Vapor Pathway (informational purposes only):	1.367E+02	mg/kg
Soil Saturation Limit, C_{sat}:	3.730E+00	mg/kg
Retardation Factor, R:	2,365.9	unitless

C_{sat} corresponds to the total soil chemical concentration saturated in soil.
R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

Chemical of concern: The name of the chemical as entered by the user.

Most stringent soil concentration based on evaluation of the direct contact pathway and the leaching pathway (mg/kg): The worksheet calculates protective soil concentrations based on the direct contact pathway and the leaching pathway (protection of groundwater). The lower (most stringent) of these two concentrations is presented in the table.

Natural background soil concentration (mg/kg): This is the chemical-specific natural background concentration entered by the user.

Practical quantitation limit for soil (mg/kg): This is the chemical-specific practical quantitation limit entered by the user.

Soil cleanup level (mg/kg): The soil cleanup level presented in the table is the most stringent concentration based on evaluation of the direct contact pathway and the leaching pathway

unless that concentration is more stringent than either the natural background concentration or the PQL. If the calculated concentration is lower (more stringent) than either the natural background concentration or the PQL, then the worksheet adjusts the calculated concentration upward to the natural background concentration or the PQL, whichever is higher (less stringent).

Soil saturation limit (C_{sat}) (mg/kg): The soil saturation limit corresponds to the chemical concentration in soil at which sorption limits of the soil particles, solubility limits of the soil pore water, and saturation of soil pore air have all been reached. It is an indicator (a theoretical threshold) that the chemical may exist as a separate pure phase in the soil and, if it is a liquid, may exist as a nonaqueous phase liquid with additional hazards to groundwater quality.

Retardation factor (R) (unitless): The retardation factor is the ratio of the groundwater flow velocity to contaminant migration velocity. If the retardation factor is "10", the contaminant plume in the saturated zone would move on average ten times slower than the groundwater flow. This result is provided so that the user can assess the chemical's relative mobility in the groundwater. The result is not used in calculating the soil cleanup level.

2.4.2 Summary of results by exposure pathway

The second table (example shown in **Figure 2-9**) displays the results of more detailed calculations for the direct contact pathway, the leaching pathway, and vapor pathway to allow the user to determine the basis of the cleanup level.

Figure 2-9: Summary of Calculation for Each Exposure Pathway

2. Summary of Calculation for each Exposure Pathway

Summary by Exposure Pathway

			Method B *Unrestricted Land* @ HQ=1.0; RISK =1.0E-6		*Method C* *Industrial Land Use* @ HQ=1.0; RISK =1.0E-5	
			Ingestion only	Ingestion & Dermal	Ingestion only	Ingestion & Dermal
Soil Direct Contact	Under the Current Condition	HQ? @ Exposure Point	1.250E-01	1.800E-01	2.857E-03	1.500E-02
		RISK? @ Exposure Point	1.700E-06	2.448E-06	1.295E-07	6.800E-07
	Target Soil CUL? mg/kg	@HQ=1.0	4.000E+01	2.778E+01	1.750E+03	3.333E+02
		@RISK =1.0E-6 or 1.0E-5	2.941E+00	2.042E+00	3.860E+02	7.353E+01

			Method B @ HQ=1.0; RISK =1.0E-6	*Method C* @ HQ=1.0; RISK =1.0E-5
Protection of Potable Ground Water	Under the Current Condition	Predicted Ground Water Conc? ug/l	3.687E-01	
		HQ? @ Exposure Point	4.608E-02	2.107E-02
		RISK? @ Exposure Point	1.433E-06	1.433E-06
	Target Ground Water CUL? ug/l		2.574E-01	
	Target Soil CUL? mg/kg		3.491E+00	

			Method B @ HQ=1.0; RISK =1.0E-6	*Method C* @ HQ=1.0; RISK =1.0E-5
Protection of Air Quality *(for informational purpose only)*	Under the Current Condition	Predicted Air Conc? ug/m^3 @Exposure Point	9.415E-03	
		HQ? @ Exposure Point	N/A	N/A
		RISK? @ Exposure Point	3.658E-07	3.658E-07
	Target Air CUL? ug/m^3	@ HQ=1.0	N/A	N/A
		@ RISK=1.0E-6 or 1.0E-5	2.574E-02	2.574E-01
	Target Soil CUL? mg/kg	@ HQ=1.0	N/A	N/A
		@ RISK=1.0E-6 or 1.0E-5	1.367E+01	1.367E+02

For the **direct contact pathway**, the worksheet first calculates HQ and RISK under Method B and Method C based on the current site conditions.

- **Noncarcinogenic HQ under the current condition**: This is the hazard quotient (HQ) based on the measured soil concentration. The worksheet calculates the HQ using the direct contact equations in the regulation (ingestion only AND ingestion + dermal) and solving for HQ.
- **Carcinogenic risk under the current condition**: This is the carcinogenic risk under the current condition based on the measured soil concentration. The worksheet calculates the carcinogenic risk using the direct contact equations in the regulation (ingestion only AND ingestion + dermal) and solving for carcinogenic RISK.

For the **direct contact pathway**, the worksheet next calculates protective soil concentrations under Method B and Method C based on the regulatory standards for HQ and RISK.

- **Target soil cleanup level (CUL) @ HQ = 1**: This is the protective soil concentration based on noncarcinogenic effects. The worksheet calculates the protective soil concentration using the direct contact equations in the regulation (ingestion only AND ingestion + dermal).
- **Target soil CUL @ RISK = 1 x 10^{-6} (Method B) or 1 x 10^{-5} (Method C)**: This is the protective soil concentration based on carcinogenic risk. The worksheet calculates the protective soil concentration using the direct contact equations in the regulation (ingestion only AND ingestion + dermal).

For the **leaching pathway (protection of potable groundwater)**, the worksheet first calculates the predicted groundwater concentration based on current site conditions using the 3-phase model and then calculates the HQ and RISK under Method B and Method C based on the predicted groundwater concentration.

- **Noncarcinogenic HQ under the current condition**: This is the hazard quotient (HQ) based on the measured soil concentration and the predicted groundwater concentration. The worksheet calculates the HQ using the equation in the regulation and solving for HQ.
- **Carcinogenic risk under the current condition**: This is the carcinogenic risk based on the measured soil concentration and the predicted groundwater concentration. The worksheet calculates the RISK using the equation in the regulation and solving for carcinogenic RISK.

For the **leaching pathway**, the worksheet next calculates the soil concentration that is protective of groundwater under either Method B or Method C using the 3-phase model. The protective soil concentration is based on the target groundwater cleanup level calculated using the groundwater worksheet or defined by the user.

2.5 Output – Adjustment of result

As noted previously (see Section 1.4.1), the soil cleanup levels calculated using the soil worksheet **DO NOT** account for several factors. Consequently, to establish a soil cleanup level under the regulation, the cleanup level calculated using the worksheet may need to be manually adjusted to account for the following:

- Concentrations established under applicable state and federal laws (WAC 173-340-740[xviii] (3)(b)(i) or WAC 173-340-745[xix](5)(b)(i))

- Terrestrial ecological impacts (see WAC 173-340-740[xviii](3)(b)(ii) or WAC 173-340-745[xix](5)(b)(ii))
- Impacts on air quality (vapor pathway) (see WAC 173-340-740(3)(b)(iii)(C), (c)(iv) or WAC 173-340-745(5)(b)(iii)(C), (c)(iv))
- Residual saturation (see WAC 173-340-747[xxviii](2)(b) and (10))
- Total site risk (see WAC 173-340-740(5)(a) or WAC 173-340-745(6)(a))

Chapter 3. Calculating Potable Groundwater Cleanup Levels (Groundwater Worksheet)

The Worksheet for Calculating Potable Groundwater Cleanup Levels (groundwater worksheet) provides tools for calculating cleanup levels for the ingestion of potable groundwater. This worksheet calculates a Method B or Method C potable groundwater cleanup level[14]. The worksheet uses the equations in the regulation (see Appendix D).The worksheet does **NOT** provide tools for calculating cleanup levels for nonpotable groundwater.

3.1 Accessing the groundwater worksheet

The groundwater worksheet is accessed by selecting the **Calc Groundwater CUL** button in Part 5 of the soil worksheet described in Section 2.3.5 **Input Data – Part 5: Target Groundwater Cleanup Level**, above.

3.2 Equations and parameters

The worksheet uses the standard equations for calculating potable groundwater cleanup levels provided in the regulation (see Appendix D). For each of the parameters used in the equations, default assumptions (values) are set forth in the regulation to calculate **standard** Method B or C[15] cleanup levels. Under **modified** Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The regulation specifically describes which parameters may be adjusted and how they may be adjusted.

- **IF** the regulation does not allow a parameter to be adjusted, **THEN** the worksheet uses the default value for that parameter provided in the regulation. Also, the parameter is not listed in the worksheet and the user may not input data for that parameter.

- **IF** the regulation allows a parameter to be adjusted, **THEN** the parameter is listed in the worksheet and the user may input either the default value provided in the regulation or a site-specific or chemical-specific value derived under the regulation.

[14] Important, see cautions for use of the groundwater worksheet in Section 1.4.2.
[15] Method C groundwater cleanup levels based on potable water ingestion may only be used at sites qualifying under the strict conditions set forth in WAC 173-340-706(1). Contact Ecology for methods to evaluate hazardous substances in groundwater that may qualify for a Method C groundwater cleanup level in accordance with WAC 173-340-706(1).

3.3 User input – Soil and groundwater worksheets

To calculate a potable groundwater cleanup level, the Workbook requires the user to input data for several parameters, some of which are listed in the soil worksheet.

The following parameters necessary for calculating a potable groundwater cleanup level are listed in the **soil worksheet** and must be entered there.

- Oral Reference Dose (***RfD$_o$***) – Part 2
- Oral Carcinogenic Potency Factor (***CPF$_o$***) – Part 2
- Inhalation Correction Factor (***INH***) – Part 3

The following parameters necessary for calculating a potable groundwater cleanup level are listed in Part 1 of the **groundwater worksheet** and must be entered there.

- Practical Quantitation Limit for Groundwater (if known)
- Natural Background Groundwater Concentration (if known)
- Most stringent groundwater concentration based on applicable state and federal laws

This worksheet requires the user to provide information listed on the left side (see **Figure 3-1**). Data is entered in the corresponding non-shaded (white) boxes on the right.

Figure 3-1: Example Method B Groundwater Cleanup Levels

Name of Chemical: ***DDT***	
1. Calculation of Method B Cleanup Levels for Potable Groundwater	
Basis for Groundwater Concentration	Concentration, ug/l
Concentration based on non-carcinogenic risk @ HQ=1.0	8.000E+00
Concentration based on carcinogenic risk @ Risk = 1 in 1,000,000 (1.0E-6)	2.574E-01
Concentration based on carcinogenic risk @ Risk = 1 in 100,000 (1.0E-5)	2.574E+00
Enter Practical Quantitation Limit of Groundwater	0.01
Enter Natural Background Level of Groundwater	
Enter Most stringent concentration based on Applicable State or Federal Laws	
Method B Potable Groundwater Cleanup Level =	2.574E-01

Practical quantitation limit (PQL) for groundwater (if known): This parameter is used to adjust the groundwater cleanup level as provided in WAC 173-340-720[xiii](7)(c), if necessary. The parameter is chemical-specific. The PQL is the lowest concentration of the contaminant that

can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using Department-approved methods. The analytical laboratory or site manager can assist the user in identifying the appropriate PQL. Enter the PQL for the chemical, if known. If the PQL is not known, leave the entry box blank.

Natural background groundwater concentration (if known): This parameter is used to adjust the groundwater cleanup level as provided in WAC 173-340-720[xiii](7)(c), if necessary. The parameter is chemical- and site-specific. Enter the natural background groundwater concentration, if known. Methods for defining natural background concentrations are provided in WAC 173-340-709[xxii]. Ecology has published information on arsenic background levels in groundwater (*Natural Background Groundwater Arsenic Concentrations in Washington State: Study Results, Publication No. 14-09-044*[xxix]). If the natural background concentration is not known, leave the entry box blank.

Most stringent groundwater concentration based on applicable state or federal laws: This parameter is used to calculate a groundwater cleanup level and is chemical-specific. Enter the most stringent (lowest) groundwater concentration (criteria) established under applicable state or federal law for the chemical of concern. Groundwater concentrations (criteria) established under applicable state or federal law are published in.

THIS COMPLETES DATA ENTRY FOR THE GROUND WATER WORKSHEET. SAVE YOUR WORK BEFORE CONTINUING.

3.4 Output – Interpreting the result

For hazardous substances for which sufficiently protective, health-based concentrations have been established under applicable state and federal laws, the worksheet establishes a groundwater cleanup level based on the most stringent of those concentrations. A concentration established under applicable state and federal laws is sufficiently protective if the excess cancer risk does not exceed 1 in 100,000 (1×10^{-5}) and the hazard quotient does not exceed one (1). If the concentration is not sufficiently protective, the worksheet calculates a protective concentration by adjusting the concentration downward in accordance with WAC 173-340-720(7)(b), using the equations provided in the regulation.

For hazardous substances for which health-based concentrations have **not** been established under applicable state and federal laws, the worksheet calculates a protective concentration using the equations provided in the regulation.

If the groundwater cleanup level is lower (more stringent) than either the natural background concentration or the PQL, then the worksheet adjusts the cleanup level upward to the natural background concentration or the PQL, whichever is higher (less stringent).

3.5 Output – Adjustment of result

As noted previously (see Section 1.4.2), the potable groundwater cleanup levels calculated using the groundwater worksheet **DO NOT** account for several factors. Consequently, to establish a potable groundwater cleanup level under the regulation, the cleanup level calculated using the worksheet may need to be manually adjusted to account for the following:

- Concentrations based on protection of air quality (vapor pathway[16])
- Concentrations based on potential surface water impacts (see WAC 173-340-720[xiii](4)(b)(ii) and (5)(b)(ii))
- Nonaqueous phase liquid (NAPL) limitation[17] (see WAC 173-340-720(7)(d))
- Total site noncancer hazard and risk (see WAC 173-340-720(7)(a))

3.6 Output – Transfer of adjusted result to soil worksheet

To calculate a corresponding soil cleanup level using the soil worksheet, the potable groundwater cleanup level calculated using the groundwater worksheet must be manually adjusted (as described above) and then manually entered in the soil worksheet. The Workbook **DOES NOT** automatically enter the result from the groundwater worksheet.

[16] To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action* at https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Vapor-intrusion-overview

[17] The cleanup level determined in WAC 173-340-720 shall not exceed a concentration that would result in NAPL being present in or on the groundwater. See WAC 173-340-720(7)(d).

Appendix A: Equations and Default Values for Calculating Protective Soil Concentrations Based on the Direct Contact Pathway

Equations 740-1 and 745-1: Soil Direct Contact (Ingestion Only) – Noncarcinogens

$$C_{soil} = \frac{RfD_o \times ABW \times UCF \times HQ \times AT}{SIR \times AB1 \times EF \times ED}$$

Parameter	Definition	Default Value Method B Equation 740-1	Default Value Method C Equation 745-1	Units
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
HQ	Hazard quotient	1	1	unitless
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit Conversion Factor	1.0E+6	1.0E+6	mg/kg
AT	Averaging time	6.0	20	years
EF	Exposure frequency	1.0	0.4	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
AB1	Gastrointestinal absorption fraction	1.0	1.0	unitless
RfD_o	Oral reference dose	Chemical-specific	Chemical-specific	mg/kg-day

Equations 740-2 and 745-2: Soil Direct Contact (Ingestion Only) – Carcinogens

$$C_{soil} = \frac{RISK \times ABW \times AT \times UCF}{CPF_o \times SIR \times AB1 \times EF \times ED}$$

Parameter	Definition	Default Value Method B Equation 740-5	Default Value Method C Equation 745-5	Units
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit Conversion Factor	1.0E+6	1.0E+6	mg/kg
AT	Averaging time	75	75	years
EF	Exposure frequency	1.0	0.4	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
AB1	Gastrointestinal absorption fraction	1.0	1.0	unitless
CPF_o	Oral cancer potency factor	Chemical-specific	Chemical-specific	kg-day/mg

Equations 740-4 and 745-5: Soil Direct Contact (Ingestion + Dermal) – Noncarcinogens

For hazardous substances that are part of a petroleum mixture, cleanup levels based on noncancer effects must be calculated using Equation 740-4 under Method B, and 745-4 under Method C. These equations differ from 740-1 by including the dermal contact pathway. See WAC 173-340-740[xviii](3)(b)(iii)(B)(III) and WAC 173-340-745[xix](5)(b)(iii)(B)(III).

For hazardous substances other than petroleum mixtures, cleanup levels for dermal contact with the soil must be evaluated whenever the proposed changes to Equations 740-1/745-1 or 740-2/745-2 would result in a significantly higher soil cleanup level than would be calculated without the proposed changes. See WAC 173-340-740(3)(c)(iii) and WAC 173-340-745(5)(c)(iii).

$$C_{soil} = \frac{HQ \times ABW \times AT}{EF \times ED \times \left[\left(\frac{1}{RfD_o} \times \frac{SIR \times AB1}{10^6 mg/kg}\right) + \left(\frac{1}{RfD_d} \times \frac{SA \times AF \times ABS_d}{10^6 mg/kg}\right)\right]}$$

Parameter	Definition	Default Value Method B Equation 740-4	Default Value Method C Equation 745-4	Units
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
HQ	Hazard quotient	1	1	unitless
ABW	Average body weight over the exposure duration	16	70	kg
AT	Averaging time	6.0	20	years
EF	Exposure frequency	1.0	0.7	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
AB1	Gastrointestinal absorption fraction	1.0	1.0	unitless
SA	Dermal surface area	2,200	2,500	cm^2
AF	Adherence factor	0.2	0.2	mg/cm^2-day
ABS_d	Dermal absorption fraction	*See* Note **(1)**	*See* Note **(1)**	unitless
RfD_o	Oral reference dose	Chemical-specific	Chemical-specific	mg/kg-day
RfD_d	Dermal reference dose	*See* Note **(2)**	*See* Note **(2)**	mg/kg-day
GI	Gastrointestinal absorption conversion factor	*See* Note **(3)**	*See* Note **(3)**	unitless

Notes:

(1) May use chemical-specific values or the following defaults: 0.01 for inorganic hazardous substances; 0.0005 for volatile organic compounds with vapor pressure ≥ benzene; 0.03 for volatile organic compounds with vapor pressure < benzene; 0.1 for other hazardous substances.

(2) Derived by ***RfD_o*** x ***GI*** (see Note 3).

(3) May use chemical-specific values or the following defaults: 0.2 for inorganic hazardous substances; 0.8 for volatile organic compounds; 0.5 for other organic hazardous substances.

Equations 740-5 and 745-5: Soil Direct Contact (Ingestion + Dermal) – Carcinogens

For hazardous substances that are part of a petroleum mixture, cleanup levels based on cancer effects must be calculated using Equations 740-5 and 745-5. These equations differ from 740-2 by including the dermal contact pathway. See WAC 173-340-740[xviii](3)(b)(iii)(B)(III) and WAC 173-340-745[xix](5)(b)(iii)(B)(III).

For hazardous substances other than petroleum mixtures, cleanup levels for dermal contact with the soil must be evaluated whenever the proposed changes to Equations 740-1/745-1 or 740-2/745-2 would result in a significantly higher soil cleanup level than would be calculated without the proposed changes. See WAC 173-340-740(3)(c)(iii) and 173-340-745(5)(c)(iii).

$$C_{soil} = \frac{RISK \times ABW \times AT}{EF \times ED \times \left[\left(\frac{SIR \times AB1 \times CPF_o}{10^6 mg/kg}\right) + \left(\frac{SA \times AF \times ABS_d \times CPF_d}{10^6 mg/kg}\right)\right]}$$

Parameter	Definition	Default Value Method B Equation 740-5	Default Value Method C Equation 745-5	Units
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	16	70	kg
AT	Averaging time	75	75	years
EF	Exposure frequency	1.0	0.7	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
AB1	Gastrointestinal absorption fraction	1.0	1.0	unitless
SA	Dermal surface area	2,200	2,500	cm^2
AF	Adherence factor	0.2	0.2	mg/cm^2-day
ABS_d	Dermal absorption fraction	*See* Note **(1)**	*See* Note **(1)**	unitless
CPF_o	Oral cancer potency factor	Chemical-specific	Chemical-specific	kg-day/mg
CPF_d	Dermal cancer potency factor	*See* Note **(2)**	*See* Note **(2)**	kg-day/mg
GI	Gastrointestinal absorption conversion factor	*See* Note **(3)**	*See* Note **(3)**	unitless

Notes:

(1) May use chemical-specific values or the following defaults: 0.01 for inorganic hazardous substances; 0.0005 for volatile organic compounds with vapor pressure ≥ benzene; 0.03 for volatile organic compounds with vapor pressure < benzene; 0.1 for other hazardous substances.

(2) Derived by ***CPF_o*** ÷ ***GI*** (see Note 3).

(3) May use chemical-specific values or the following defaults: 0.2 for inorganic hazardous substances; 0.8 for volatile organic compounds; 0.5 for other organic hazardous substances.

Appendix B: Equations and Default Values for Calculating Protective Soil Concentrations Based on the Leaching Pathway (Protection of Groundwater)

THREE-PHASE PARTITIONING

Equation 747-1: Three-Phase Partitioning Equilibrium Equation.

$$C_s = C_w \times UCF \times DF \times \left[K_d + \frac{\theta_w + \theta_a \times H_{cc}}{\rho_b}\right]$$

Parameter	Definition	Default Value (Unsaturated Zone)	Default Value (Saturated)	Units
C_s	Soil concentration	(calculated)	(calculated)	mg/kg
C_w	Groundwater cleanup level established under WAC 173-340-720	Chem-specific	Chem-specific	ug/L
UCF	Unit conversion factor	1E-3	1E-3	mg/ug
DF	Dilution factor	20	1	unitless
K_d	Distribution coefficient	Chem-specific **(1)**	Chem-specific **(1)**	L/kg
θ_w	Water-filled soil porosity	0.3	0.43	unitless, ml/ml
θ_a	Air-filled soil porosity	0.13	Zero	unitless, ml/ml
H_{cc}	Henry's law constant	Chem-specific **(2)**	Chem-specific **(2)**	unitless
ρ_b	Dry soil bulk density	1.5	1.5	kg/L

Notes:

(1) For ***K_d***, the regulation specifies default values for certain chemicals. It also has procedures for establishing chemical-specific values. See WAC 173-340-747[xxviii](4)(c).

(2) For ***H_{cc}***, the regulation specifies default values for certain chemicals. It also has procedures for establishing chemical-specific values. See WAC 173-340-747(4)(d).

Equation 747-2: Derivation of a Distribution Coefficient (***K_d***) for Organic Hazardous Substances Based on the Soil Organic Carbon-Water Partitioning Coefficient (***K_{oc}***)

$$K_d = K_{oc} \times f_{oc}$$

Parameter	Definition	Default Value	Units
K_d	Distribution coefficient	(Calculated or site-specific)	L/kg
K_{oc}	Soil organic carbon-water partitioning coefficient	Chem-specific **(1)**	L/kg
f_{oc}	Soil fraction of organic carbon	0.001	unitless, g/g

Note:

(1) For ***K_{oc}***, the regulation specifies default values for certain chemicals. It also has procedures for establishing chemical-specific values. See WAC 173-340-747[xxviii](4)(c)(i).

Equation 747-3: Deriving a Dilution Factor from Site-Specific Estimates of Infiltration and Groundwater Flow Volume

$$DF = \frac{(Q_p + Q_a)}{Q_p} = 1 + \frac{Q_a}{Q_p}$$

Parameter	Definition	Default Value	Units
DF	Dilution factor	(calculated)	unitless
Q_p	Flowrate of water infiltrating (*see* Equation 747-5)	(calculated)	m^3/yr
Q_a	Ground water flowrate (*see* Equation 747-4)	(calculated)	m^3/yr

Equation 747-4: Calculating Groundwater Flowrate (***Q_a***)

$$Q_a = K \times A \times I$$

Parameter	Definition	Default Value	Units
Q_a	Ground water flowrate	(calculated)	m^3/yr
K	Hydraulic conductivity	Site-specific measurement	m/yr
A	Cross-sectional area of aquifer mixing zone **(1)**	Site-specific measurement	m^2
I	Hydraulic gradient	Site-specific measurement	unitless, m/m

Note:

(1) The aquifer mixing zone thickness shall not exceed 5 meters in depth and be equal to a unit width of 1 meter, unless it can be demonstrated empirically that the mixing zone thickness exceeds 5 meters.

Equation 747-5: Calculating the Flowrate of Water Infiltrating (***Q_p***)

$$Q_p = L \times W \times Inf$$

Parameter	Definition	Default Value	Units
Q_p	Flowrate of water infiltrating	(calculated)	m^3/yr
L	Estimated length of contaminant source area parallel to groundwater flow	Site-specific measurement	m
W	Unit width of contaminant source area	1.0	m
Inf	Infiltration rate	Site-specific measurement **(1)**	m/yr

Note:

(1) A default value may be used. For sites **west** or **east** of the Cascade Mountains, the default annual infiltration value shall be **70 percent** or **25 percent**, respectively, of the average annual precipitation amount.

Appendix C: Equations and Default Values for Calculating Air Cleanup Levels

Equation 750-1: Air Cleanup Levels – Noncarcinogens

$$Air\ Cleanup\ Level\ (\frac{\mu g}{m^3}) = \frac{RfD_i \times ABW \times UCF \times HQ \times AT}{BR \times ABS_i \times EF \times ED}$$

Parameter	Definition	Default Value Method B Equation 750-1	Default Value Method C Equation 750-1	Units
HQ	Hazard quotient	1	1	unitless
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit Conversion Factor	1.0E+3	1.0E+3	µg/mg
AT	Averaging time	6.0	6.0	years
EF	Exposure frequency	1.0	1.0	unitless
ED	Exposure duration	6.0	6.0	years
BR	Breathing rate	10	20	m^3/day
ABS_i	Inhalation absorption fraction	1.0	1.0	unitless
RfD_i	Inhalation reference dose	Chemical-specific	Chemical-specific	mg/kg-day

Equation 750-2: Air Cleanup Levels – Carcinogens

$$Air\ Cleanup\ Level\ (\frac{\mu g}{m^3}) = \frac{RISK \times ABW \times UCF \times AT}{CPF_i \times BR \times ABS_i \times EF \times ED}$$

Parameter	Definition	Default Value Method B Equation 750-2	Default Value Method C Equation 750-2	Units
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	70	70	kg
UCF	Unit Conversion Factor	1,000	1,000	µg/mg
AT	Averaging time	75	75	years
EF	Exposure frequency	1.0	1.0	unitless
ED	Exposure duration	30	30	years
BR	Breathing rate	20	20	m^3/day
ABS_i	Inhalation absorption fraction	1.0	1.0	unitless
CPF_i	Inhalation cancer potency factor	Chemical-specific	Chemical-specific	kg-day/mg

Appendix D: Equations and Default Values for Calculating Potable Groundwater Cleanup Levels

Equation 720-1: Potable Groundwater Cleanup Levels – Noncarcinogens

$$Potable\ Groundwater\ Cleanup\ Level\ (\mu g/L) = \frac{RfD_o \times ABW \times UCF \times HQ \times AT}{DWIR \times INH \times DWF \times ED}$$

Parameter	Definition	Default Value Method B	Default Value Method C	Units
RfD_o	Oral reference dose	Chemical-specific	Chemical-specific	mg/kg-day
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit conversion factor	1,000	1,000	µg/mg
HQ	Hazard quotient	1.0	1.0	unitless
AT	Averaging time	6	6	years
DWIR	Drinking water ingestion rate	1.0	2.0	L/day
INH	Inhalation correction factor (1)	Chemical-specific **(1)**	Chemical-specific **(1)**	unitless
DWF	Drinking water fraction	1.0	1.0	unitless
ED	Exposure duration	6	6	years

Note:

(1) Use value of 2 for volatile organic compounds and 1 for all other substances.

Equation 720-2: Potable Groundwater Cleanup Levels – Carcinogens

$$Potable\ Groundater\ Cleanup\ Level\ (\mu g/L) = \frac{RISK \times ABW \times AT \times UCF}{CPF_o \times DWIR \times ED \times INH \times DWF}$$

Parameter	Definition	Default Value Method B	Default Value Method C	Units
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	70	70	kg
AT	Averaging time	75	75	years
UCF	Unit conversion factor	1,000	1,000	µg/mg
CPF_o	Oral carcinogenic potency factor	Chemical-specific	Chemical-specific	kg-day/mg
DWIR	Drinking water ingestion rate	2.0	2.0	L/day
INH	Inhalation correction factor	Chemical-specific **(1)**	Chemical-specific **(1)**	unitless
DWF	Drinking water fraction	1.0	1.0	unitless
ED	Exposure duration	30	30	years

Note:

(1) Use value of 2 for volatile organic compounds and 1 for all other substances.

Endnotes

[i] https://apps.ecology.wa.gov/publications/summarypages/2509200.html
[ii] https://apps.ecology.wa.gov/publications/SummaryPages/1009057.html
[iii] https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/contamination-cleanup-tools/clarc/guidance
[iv] https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/ToxicityChemPropPetroleumMixtures.pdf
[v] https://apps.ecology.wa.gov/publications/SummaryPages/2209059.html
[vi] https://apps.ecology.wa.gov/publications/SummaryPages/0909047.html
[vii] https://apps.ecology.wa.gov/publications/SummaryPages/97602.html
[viii] https://apps.ecology.wa.gov/publications/SummaryPages/1509049.html
[ix] https://apps.ecology.wa.gov/publications/SummaryPages/1909043.html
[x] https://ecology.wa.gov/contact
[xi] https://app.leg.wa.gov/wac/default.aspx?cite=173-340
[xii] https://ecology.wa.gov/clarc
[xiii] https://app.leg.wa.gov/WAC/default.aspx?cite=173-340-720
[xiv] https://app.leg.wa.gov/WAC/default.aspx?cite=173-340-750
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