



Alberta tier 2 soil and groundwater remediation guidelines

Alberta 

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Part A: Overview of Alberta Guidelines and Implementation Framework

1. Introduction

1.1 General

This document focuses on *Alberta Tier 2 Soil and Groundwater Remediation Guidelines* (Tier 2) and the manner in which they should be applied.

The Tier 1 approach has been described in detail in the companion *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (Tier 1) (ESRD, 2007 and updates). The Tier 1 approach is based on the assumption that all exposure pathways and receptors relevant to a particular land use are actually present. Under Tier 2 it may be possible to screen out certain exposure pathways and/or modify the Tier 1 guidelines on the basis of site conditions. This document describes how the Tier 2 approach might be used to develop remediation objectives for a site. For more information on the overall framework for remediation see the *Alberta Contaminated Sites Policy Framework* (ESRD, 2014b)

Applying Tier 2 requires more information from the site than Tier 1 guidelines. This additional information allows the assessor to develop guidelines that are tailored to the particular characteristics of the site. When a site has characteristics that make it more sensitive than the Tier 1 assumptions, the resulting Tier 2 guidelines may be more restrictive than Tier 1 values. Sites that are less sensitive may have Tier 2 guidelines that are less restrictive than Tier 1 values, but which deliver the same level of human and ecological health protection because they are tailored to that specific site.

When adverse effects are evident, contaminants must be managed to alleviate adverse effects, regardless of whether a site meets Tier 1 or 2 remediation guidelines.

This document supports the Government of Alberta's *Contaminated Sites Policy Framework* (ESRD, 2014b) and acts as a companion document to Tier 1, *Alberta Exposure Control Guide* (AEP, 2016b), and *Alberta Environmental Site Assessment Standard* (AEP, 2016a).

There are two options available under Tier 2 remediation guideline development, namely modification of the generic Tier 1 guidelines or development of site-specific remediation objectives. This document briefly describes both options and gives specific details related to modification of generic Tier 1 guidelines. Development of site-specific remediation objectives requires more detailed planning and a more detailed site-specific ecological and human health risk assessment than are described in this document. For this option, more interaction with Alberta Environment and Parks is expected and only general principles are provided in the Tier 2 document. For more information on the site-specific Tier 2 option, see *Supplemental Guidance on Site-Specific Risk Assessments in Alberta* (Alberta SSRA Guide) (GOA, 2022b)

This document is divided into two parts. Part A consists of an overview of the tiered framework and provides guidance for proceeding through the assessment and decision processes at each tier, as well as considerations and requirements related to the implementation of risk management strategies. Part B contains prescriptive guidance for developing Tier 2 remediation objectives by modification of Tier 1 guidelines, including eligible exposure pathways, parameter adjustments, data requirements and calculation procedures. Detailed guidance on the development of Tier 2 objectives through site-specific risk assessment is contained in the Alberta SSRA Guide (GOA, 2022b).

1.2 Relation to Alberta's Framework for Management of Contaminated Sites

Alberta's framework for contaminated sites management is described in the *Contaminated Sites Policy Framework* (ESRD, 2014b).

This document further describes the principles for management of substance releases, focusing on the Alberta Tier 2 option for management of contaminated sites. It is a companion document to Tier 1 and must be used in conjunction with that document. The Tier 1 companion document further describes important parameters and models that need to be maintained for implementation of Tier 2 options. Proponents will need to ensure that protection levels and model inputs are consistent with Alberta Tier 1 guidelines when using other options provided in the framework.

All submissions for site closure based the application of Tier 2 as part of a risk assessment or environmental site assessment must adhere to this document.

In keeping with Alberta's requirement for the same level of human or ecological protection, human health and ecological protection endpoints must be maintained at all management Tiers. Changes to the endpoints require ongoing administrative controls or site management and therefore would be considered under Exposure Control. When adverse effects are evident, contaminants must be managed to alleviate adverse effects, regardless of whether a site meets Tier 1 or Tier 2 remediation guidelines.

1.3 Relationship to Other Guideline Documents

This is a companion document to the *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (ESRD, 2007 and updates) and must be used in conjunction with that document as guidance for the determination and implementation of site-specific remediation objectives for the management of contaminated sites. It supports *Contaminated Sites Policy Framework* (ESRD, 2014b).

Alberta Tier 1 lists other documents that are important for application of Tier 1 and documents that form the protocols and primary technical basis for Tier 1 guidelines. These documents are equally important for Tier 2. See the *Contaminated Sites Policy Framework* (ESRD, 2014b) and Tier 1 for additional information on other guidelines.

1.4 Ongoing Commitment

Tier 2 is a living document. Alberta Environment and Parks is committed to updating the guidelines as new information and guidelines for new substances become available.

2. Alberta Policy for Use of Tier 2

Key elements of Alberta's framework for the management of contaminated sites (ESRD, 2014b) are described in the Alberta Tier 1 guidelines. These are,

- source control,
- contamination delineation, and
- contaminant management, including remediation.

These must be maintained in the same manner as described in Tier 1. For more information, see Alberta Tier 1.

2.1 Soil Protection in Alberta

2.1.1 Using Tier 2 Soil and Groundwater Remediation Objectives

Alberta Tier 2 follows the same principles as outlined in Tier 1. It is important to be familiar with Tier 1 requirements, models and parameters in order to conduct Tier 2 risk assessments in Alberta. These are further described in Tier 2. In conducting a Tier 2 you must:

- Be familiar with assumptions inherent in the models used in Tier 1 and ensure that these assumptions can be still used for Tier 2.
- Revisit all pathway and receptor relations that may be relevant to the Tier 2 decision and ensuring that all pathways and receptors that the most sensitive relations have been included in the Tier 2 decision.
- Ensure that where available, toxicity reference values established for Tier 1 decisions are followed in the Tier 2 decision. Where these are not available, toxicity reference values must be established using the method outlined in the *Guidance for Selecting Toxicity Reference Values for Alberta Tier 1 and Tier 2 Soil and Groundwater Remediation* (2017a).
- Maintain human health and ecological endpoints established in Tier 1.
- Ensure parameter and pathway modification is permitted within the Tier 2 approach that is applied.
- Ensure that unless directly part of the Tier 2 re-evaluation, parameters are consistent with the parameters listed in Tier 1.

As with Tier 1, guidelines developed using Tier 2 are **not** "pollute-up-to" levels. Sources must not be left uncontrolled until cumulative releases result in an exceedance of Tier 1 or 2 soil remediation guidelines. Source control is a crucial component of pollution prevention.

While the Tier 2 approach may not define the same guidelines as outlined in Tier 1, the objectives at Tier 2 remain consistent with Tier 1. Human health and ecological protection endpoints must be maintained in keeping with Alberta Environment and Parks' requirement for the same level of human and ecological protection at all tiers of management.

2.1.2 Background Soil Quality

For the purpose of applying *Alberta Tier 1* or *Alberta Tier 2 Soil and Groundwater Remediation Guidelines*, the background concentration of a substance in soil or groundwater is defined as:

1. The natural concentration of that substance in the absence of any input from anthropogenic activities or sources or;
2. The background concentration in the surrounding area as a result of generalized non-point anthropogenic sources.

For more information on use of background concentration in application of Tier 1 or Tier 2, see Alberta Tier 1.

2.1.3 Land Use

Potential receptors and their exposure to soil contaminants are affected by land use. Alberta Tier 1 describes five possible land uses. These land uses can be used for decision making at Tier 2, but the requirements regarding individual land uses and parameters used for these land uses must be preserved. Similarly, if there are more sensitive land uses bordering a site, Tier 2 may allow for further refinement of risks to the more sensitive land use but the requirements for assessment of the more sensitive use must be preserved at Tier 2. For more information, see Alberta Tier 1.

2.1.4 Relationship Between Soil, Air, Groundwater and Surface Water Quality

Soil contamination interacts with air through volatilization and with water through dissolution and leaching to groundwater or runoff to surface water. Mobile soil or groundwater contamination that adds contaminant mass to air or water is automatically considered a source. Therefore it must be remediated, or the contaminant release from the soil must be controlled as noted in Tier 1.

For volatile and semivolatile contaminants, soil and groundwater contamination cannot be managed without consideration of potential to partition to soil vapour and exposure in the vapour phase to the receptor. Alberta Tier 1 soil remediation guidelines include soil concentrations that have been developed to protect indoor air quality. When soil contaminant concentrations exceed the soil remediation guideline protective of indoor air, then management of this exposure pathway is required. In this case, three options are available:

1. Remediate soil and groundwater to Tier 1 guidelines,
2. Conduct a more detailed site investigation, develop an alternate Tier 2 guideline and remediate to that guideline value, or
3. Ensure that the pathway is managed through exposure control until the risk is acceptable.

The Alberta Tier 1 soil remediation guidelines also include soil concentrations that have been developed to protect groundwater quality. When soil contaminant concentrations exceed the soil remediation guideline protective of any groundwater-governed pathway (e.g., protection of potable groundwater for drinking water, protection of groundwater for freshwater aquatic life, or other groundwater pathways), then an investigation of groundwater quality and management of the groundwater pathway is required. A Tier 2 approach may be included in investigation and management options. For groundwater pathways, Tier 2 approaches could include pathway exclusion, site-specific risk assessments, or guideline adjustments based on separation distances between the zone of contamination and the seasonally high saturated zone or the distance to the water body of concern (Part B, Section 6). A groundwater quality investigation is also strongly recommended when contaminant concentrations in soil are close to the groundwater protection guidelines because the presence of preferential flow paths can result in contaminants reaching groundwater even when general soil conditions appear not to pose a risk. It is also possible that mobile substances have leached out of the vadose zone into groundwater if sufficient time has elapsed since the release event. The purpose of the groundwater quality investigation is to determine if there is groundwater contamination resulting from associated contaminated soil rather than to monitor groundwater quality over time.

Four options are available if the Alberta Tier 1 guidelines for the protection of groundwater are breached:

1. Remediate soil and groundwater to Tier 1 guidelines,
2. Conduct a more detailed site investigation, develop an alternate Tier 2 guideline and remediate to that guideline value,
3. Some pathways may be screened out based on lateral offset distances (e.g. freshwater aquatic life – Table 5), or if there is an isolating soil layer between the contamination and a Domestic Use Aquifer (Appendix E). If exposure pathways are excluded on this basis, the Tier 2 remediation guideline can be selected from the next most protective value in the relevant Tier 1 tables (ESRD, 2007 and updates – Appendices A & B), or
4. Develop exposure control mechanisms through site-specific risk assessment (See Part A, Section 6).

2.2 Groundwater Protection in Alberta

2.2.1 Alberta's Initiatives to Protect Water Resources

Groundwater contaminants will interact with air and soil through partitioning and with surface water through migration. Groundwater cannot be managed in isolation from soil, soil vapour, surface water and aquatic ecosystems.

In the protection of groundwater quality, the strongest emphasis is placed on preventing groundwater resources from becoming contaminated. However, where contamination of this valuable public resource has resulted in an exceedance of Tier 1 or 2 guidelines, it must be remediated or managed to ensure on-going protection of human health and the environment, and the restoration of beneficial uses.

This document provides a framework to guide how contaminated groundwater should be managed in Alberta. It differs from the companion Tier 1 document (ESRD, 2007 and updates) in that it provides a method to determining Tier 2 risk-based remedial objectives to indicate when groundwater quality has been restored to an acceptable level, whereas the Tier 1 document provides generic risk based remedial objectives that may be applied to the majority of sites in Alberta.

2.2.2 Protection of Domestic Use Aquifers

The definition of a DUA is dependent on the amount of water an aquifer can produce, rather than the quality of the water in the aquifer, recognizing that technological treatment methods exist that can reduce or remove natural background substances. Furthermore, an aquifer does not have to be currently used for domestic purposes in order to be classified as a DUA, as the intent is to define and protect these aquifers for current and future use. Alberta Environment and Parks may consider any body of groundwater above the Base of Groundwater Protection¹ that is capable of a sufficient yield of water to be a DUA.

For the purpose of selecting and applying a groundwater guideline for human health protection by ingestion, a DUA is defined as a geologic unit (either of a single lithology or inter-bedded units) that is above the Base of Groundwater Protection¹ having one or more of the following properties:

- A bulk hydraulic conductivity of 1×10^{-6} m/s or greater and sufficient thickness to support a sustained yield of 0.76 L/min or greater; or
- Is currently being used for domestic purposes; or
- Any aquifer determined by Alberta Environment and Parks to be a DUA.

While it is possible that peat deposits and muskeg may meet the definition of a DUA, based on hydraulic conductivity and unit thickness, Alberta Environment and Parks does not consider peat deposits or muskeg to be a DUA because groundwater in them is unlikely to be used as a domestic source.

The DUA drinking water pathway cannot be excluded using the Tier 1 approach. However, using the Tier 2 approach, it is possible to screen out the DUA drinking water pathway under certain circumstances, such as if there is an isolating unit meeting specific properties. If a shallow large diameter well (or bored well) has been installed in a geologic unit that otherwise would not meet the definition of a DUA, the entire geological unit is not considered a DUA, but the well must be treated as a point of compliance for the DUA pathway.

For specific guidance regarding implementation, determining the sustained yield or exclusions allowed within this definition, see Appendix E.

2.2.3 Using Tier 2 Groundwater Remediation Guidelines

To ensure consistency with "pollution prevention", a key outcome of Alberta's framework for contaminated sites management, Tier 1 or Tier 2 are **not** "pollute-up-to" levels. Sources must not be left uncontrolled until cumulative releases result in an exceedance of any Tier 1 or 2 objective. This results only in further contamination, increased

¹ The Base of Groundwater Protection is the depth above which groundwater is naturally non-saline, having a natural concentration of total dissolved solids that is less than or equal to 4000 milligrams per litre. Information on the Base of Groundwater Protection is available from the Alberta Geological Survey.

remediation costs, and potential loss of water use options. Source control is a crucial component of pollution prevention.

2.2.4 Background Groundwater Quality

The background concentration of a substance in groundwater is the natural concentration of that substance in a particular groundwater zone in the absence of any input from anthropogenic activities or sources. Remediation of groundwater to below background conditions is not feasible and is not required. Accordingly, it is important to have a good understanding of background groundwater conditions at a site. For more information on requirements for background groundwater quality, see Alberta Tier 1.

2.2.5 Relationship to Soil, Air and Surface Water Quality Guidelines

Environmental media are interconnected. Contaminants in soil may leach into pore water or groundwater. Volatile compounds in groundwater may volatilize at the water table and can migrate through the soil into the interior space of buildings above. Soluble contaminants in groundwater can be transported laterally with the groundwater flow, and potentially enter a surface water body (creek, slough, lake, etc.) at the point of groundwater discharge.

Alberta Tier 1 groundwater remediation guidelines are developed to protect indoor air quality, plants and soil invertebrates, and water quality for a range of uses. Guidelines to protect a particular water use are calculated based on the corresponding water quality guideline (drinking water, aquatic life, irrigation, or livestock or wildlife watering).

Under the Alberta Tier 2 approach, it is possible to use site-specific information to evaluate risk to groundwater receptors. More details are provided in Part A below in the overview discussions found in Sections 4, 5, and 6. As a minimum, this approach will involve a more detailed delineation and collection of site-specific information to support the Tier 2 decision. Generally, under the Tier 2 approach, site-specific information is used to more closely assess the risk of the substance interacting with the receptor of concern. Receptor reference values representing a safe level of exposure (e.g. drinking water, aquatic life guidelines, toxicity reference values etc.) are not open to modification under the Tier 2 approach.

2.3 Points of Compliance

For the purpose of this document, a point of compliance is the spatial location at which a soil or groundwater quality guideline must be achieved to protect human and ecological receptors, to protect a groundwater resource, or to meet other conditions such as industrial use or groundwater management guidelines.

Points of compliance are described in Alberta Tier 1. In Tier 2 and Exposure Control, it becomes important to ensure that points of compliance are clearly defined and it is demonstrated how the approach will be maintained for the risk assessment or risk management option.

For Tier 2 risk assessments, similar rules for points of compliance are maintained as per Tier 1. This includes:

- The compliance point for the human health water ingestion pathway is everywhere within a DUA. For livestock watering, the compliance point is everywhere within the relevant livestock watering aquifer existing below agricultural or other grazing land. For irrigation, the compliance point is everywhere within the irrigation-use aquifer, where applicable. For aquatic life or wildlife receptors, the minimum point of compliance is at the point of groundwater discharge into a surface water body that is capable of supporting an aquatic ecosystem
- For terrestrial receptors (plants and soil invertebrates), the point of compliance is everywhere within the shallow soil groundwater zone (i.e. the extent of groundwater less than 3 m below ground surface) and at the point of ground surface discharge.
- For human health, direct contact, use of point of compliance is only allowed under the exposure control option.

Some additional information on how the point of compliance is used at Tier 2 or under exposure control options is discussed in Part B of this document.

2.3.1 Risk Management

Alberta's policy for risk management at contaminated sites is outlined in the *Contaminated Sites Policy Framework* (ESRD, 2014b). There are two main "tracks" for the management of risks at contaminated sites in Alberta, namely remediation to risk-based objectives and exposure control. Remediation could be conducted in accordance with generic objectives, as outlined in Alberta Tier 1. Alternatively, Tier 2 may be used as outlined in this document. Exposure control could involve the use of physical and/or chemical exposure barriers, administrative controls, or other forms of exposure management as outlined in the *Alberta Exposure Control Guide* (AEP, 2016b). Under this policy, exposure control will by its nature lead to conditions or restrictions that will preclude regulatory closure.

3. Alberta Framework for the Management of Contaminated Sites

3.1 Implementation Framework and Management Levels

The general framework for the management of contaminated sites in Alberta has three options and is illustrated by the flowchart presented in Figure 1. A more detailed framework specific to site management under the Tier 1 approach is presented in Figure 3. A brief description of the framework is provided below.

Under the Alberta framework (ESRD, 2014b), three options are provided for the management of contaminated sites as the proponent proceeds from initial site assessment to regulatory closure. The three options are:

- Tier 1 - generic remediation guidelines.
- Tier 2 - site-specific remediation guidelines based on the modification of Tier 1 guidelines.
- Exposure Control - risk management through exposure barriers or administrative controls based on site-specific risk assessment.

Regardless of the option chosen, the target level of human health and ecological protection afforded by Tier 1, Tier 2, or Exposure Control is the same.

As discussed below, regulatory closure is available for sites managed to achieve Tier 1 and Tier 2 remediation guidelines. This means that no conditions are imposed on future use of the site, within a given land use. Regulatory closure is not provided for Exposure Control. For more description on the 3 options and how they relate to each other, see the *Contaminated Sites Policy Framework* (ESRD, 2014b)

3.2 Land Use Definitions

For the purpose of developing and implementing soil and groundwater remediation guidelines in Alberta, five generic land uses have been defined – natural areas, agricultural, residential/ parkland, commercial, and industrial. Tier 1 land use definitions must be preserved for the purpose of Tier 2. For more information on the generic land use definitions, see Tier 1.

A generic land use scenario is envisioned for each category based on typical activities on these lands. Where allowable land uses, as defined by a given jurisdictional authority, differ from those noted here, an assessment of allowable receptors and potential exposure pathways must be made to ensure consistency with assumptions based on Tier 1 definitions. Where a more sensitive receptor or exposure pathway is allowed, the more sensitive land use description must be used. Assessors must determine the full range of uses allowed under the applicable zoning bylaw when determining the appropriate land use for Tier 2. If none of the generic land uses are applicable, a site-specific Tier 2 approach will be required.

3.3 Groundwater and Surface Water Use Definitions

Soils are hydrologically linked to groundwater and surface water systems. One of the objectives of Alberta's soil remediation guidelines is to manage soil-to-groundwater pathways to prevent unacceptable transfer of contaminants from the soil, which may ultimately affect groundwater and surface water use. Protection of generic water uses as defined in Tier 1 is required at Tier 2. For more information on the generic soil and groundwater definitions see Alberta Tier 1.

At Tier 2, other water use categories, for example recreation, as well as variations in water use within a defined land use category, may also need to be addressed using the Tier 2 process.

3.4 Protection of Human Health and Ecological Receptors

The following documents provide the protocols and the primary technical basis for the risk-based guidelines calculated in Alberta:

- For all compounds except petroleum hydrocarbons: *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* (CCME, 2006); and,
- For petroleum hydrocarbons: *Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil. Scientific Rationale* (CCME, 2008).
- *A Protocol for the Derivation of Groundwater Quality Guidelines for Use at Contaminated Sites* (CCME, 2015a); and
- *A Protocol for the Derivation of Soil Vapour Quality Guidelines for Protection of Human Exposures Via Inhalation of Vapours* (CCME, 2014).
- *Ecological Risk Assessment Guidance Document* (CCME, 2020).

These documents provide primary protocols and technical guidance for Tier 2. In particular, Alberta Environment and Parks follows the principles as outlined in *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* (CCME, 2006a).

Where generic input parameters or equations in this document differ from CCME protocols, this document governs generic input values for model parameters.

Tier 1 has, in many cases, simplified pathway and receptor analysis or unstated checks that are conducted in the background. At Tier 2, all pathways and receptors need to be revisited in order to determine relevance with the particular assumptions made during the Tier 2 process.

The Tier 2 guidelines outlined in Part B of this document are sufficient to make simple adjustments to Tier 1 guidelines based on single source/receptor pathway considerations and small modifications based on simple changes to model parameters.

For more complex site-specific risk assessments, the proponent must consider all aspects of the CCME protocols and ensure the most sensitive pathway/receptor relationships have been included in the risk assessment. Exposure pathways and receptors and the choice of relevant receptors will need to be reconsidered to ensure that the most sensitive and relevant receptors have been captured and appropriately assessed for the site-specific assessment.

3.4.1 Protection of Human Health

In keeping with CCME (2006a), guidelines need to be based on a critical human receptor that represents the most sensitive receptor to the substance and the most critical health effect within the land use scenario. In addition, the entire range of activities associated with the land use must be free of appreciable health risks.

Human Receptors and Exposure Pathways

The most sensitive receptor is a function of the receptor characteristics, the degree of potential exposure, the exposure pathway(s) and the chemical(s) of concern. Because Tier 2 involves a re-evaluation of Tier 1 assumptions, the assessor must ensure that the most sensitive receptor is evaluated. It may be necessary to identify the presence of uniquely sensitive receptors that are not directly described in the generic guidelines. Further guidance is available in CCME (2006a).

At Tier 1 and Tier 2, the general public is assumed to be present on agricultural, residential/parkland and commercial land. The general public is considered to incorporate all age classes and the most sensitive pathway/receptor combination must be used in establishing the appropriate risk-based guideline. At industrial sites, only adults are assumed to be present, which precludes the use of the child exposure model parameters. Human exposure is assumed to be minimal in Tier 1 natural areas, except where underlying groundwater is considered to be a potential source of drinking water. This assumption, however, may need to be re-evaluated under Tier 2 depending on changes to other pathways and receptors since even minimal contact may be important in the re-evaluation.

Where any land use definitions differ from the potential uses of a site, the risk assessment must be modified to consider the most sensitive case.

The following human exposure pathways are considered, as a minimum, in the derivation of Tier 2 remediation objectives where appropriate to the defined land use (based on CCME, 2006a):

- Direct contact with contaminated soil (soil ingestion, dermal contact with soil, inhalation of soil and soil-derived particulates)
- Ingestion of groundwater or surface water (potable water scenario)
- Inhalation of vapours migrating into indoor air
- Ingestion of produce, meat and dairy products.

More detailed descriptions regarding specific considerations under each of these categories can be found in derivation of human health and environmental endpoints from the CCME references listed. Information on the application to the Natural Area land use may be found in the companion Tier 1.

Human Health Protection Endpoints

The human health protection endpoint is the same at all tiers of contaminated site management, and is expressed in terms of an allowable exposure level at which the likelihood of a receptor experiencing adverse health effects is essentially negligible. Toxicity reference values for human health are specified in Tier 1 and these must be adhered to at Tier 2. Where Tier 1 values are not available, appropriate toxicity reference values must be chosen using the *Guidance for Selecting Toxicity Reference Values for Alberta Tier 1 and Tier 2 Soil and Groundwater Remediation Guidelines* (AEP 2017a).

For a non-threshold chemical, where values are not available from Tier 1, the incremental lifetime cancer risk must not exceed 1 in 100,000 (1×10^{-5}).

3.4.2 Ecological Protection

Risk-based remediation guidelines are required to fulfill two main goals from the ecological standpoint: protection of ecological receptors expected to be present at a site based on the setting and land use, and preservation of an appropriate level of ecological function of the site and its ecosystem components.

This document provides general guidance on how to develop remediation guidelines for protection of ecological receptors. More detailed protocol descriptions can be found in CCME (2006a, 2008, 2020).

Ecological Receptors and Exposure Pathways

A first step in developing risk-based remediation guidelines for ecological protection is to determine the ecological components potentially at threat from a substance release. Ecological receptors at a typical contaminated site, within the range of generic land uses considered in the development of the Alberta guidelines, span a range of trophic levels including soil-dependent organisms (plants, soil invertebrates and crops), soil function (e.g. nutrient and energy cycling, related microbial activities), and higher order consumers (terrestrial and avian wildlife and livestock). In addition, based on the potential for groundwater underlying a site to discharge to a surface water body, aquatic receptors including invertebrates, fish, and waterfowl are considered. Receptors assigned to each land use for the purpose of guideline derivation must be sufficiently sensitive to capture effects to species most at threat from contaminated soil or food sources for the defined ecological use.

The following ecological exposure pathways are considered in the derivation of remediation objectives at Tier 1 and Tier 2 where appropriate to the defined land uses (based on CCME, 2006a):

- Soil contact with plants and invertebrates
- Soil and food ingestion by livestock and wildlife, including secondary and tertiary consumers
- Soil nutrient cycling processes
- Protection of surface water sustaining aquatic life
- Protection of groundwater and surface water used for livestock watering

- Protection of surface water used for wildlife watering
- Protection of groundwater and surface water used for irrigation

In addition, there may be other ecological considerations that must be considered on a site-specific basis. More detail on this can be found in CCME (2006a, 2008, 2020).

Ecological Protection Endpoints

Ultimately, ecological protection endpoints must be chosen to provide assurance that the ecological function will sustain activity within a given land use function (CCME 2006a). Ecological protection endpoints are the same at all levels of management, subject in some cases to a reduced requirement for ecological function based on land use.

Protection of ecological receptors is based on ensuring that exposure does not exceed appropriate toxicological benchmarks. At higher trophic levels, these benchmarks are based on designated chronic effects levels derived for specific species at the population level; for plants and soil invertebrates the benchmarks are determined and applied on an ecosystem basis through the use of species sensitivity distributions. A lower level of ecological functioning allowed at commercial and industrial sites is addressed by means of a less stringent protection level for plants and soil invertebrates.

3.4.3 Considerations Other than Toxicity

For complex risk assessments or where major changes to generic endpoints, models or pathway/receptor relationships are proposed, factors other than toxicity must be considered in the risk assessment.

Contaminants may have adverse effects in addition to producing toxic responses in human and ecological receptors. These may include aesthetic concerns (e.g. offensive odours), explosive hazards, or damage to utilities and infrastructure. If there is evidence that a contaminant may cause effects beyond toxicity to human and ecological receptors, then this evidence should be evaluated.

Certain contaminants may potentially degrade into more toxic or more mobile chemicals (e.g., degradation of trichloroethylene to vinyl chloride). Since degradation rates are affected by site-specific factors, potential for these types of effects and degradation products must be considered when developing Tier 2 remediation objectives.

3.5 Conditions and Restrictions Associated with Tier 2 and Exposure Control

The Alberta soil and groundwater remediation guidelines and implementation framework are intended to provide the same high level of protection of human health and the environment at all levels or tiers of site management. For Tier 1, this is ensured by the use of relatively conservative assumptions in the derivation of the risk-based numerical guidelines, such that the values can be applied to the large majority of sites within a land use category without condition or restriction.

Management under Tier 2 allows for incorporation of site-specific data into the development of appropriate remediation guidelines. It must deliver the same level of health and environmental protection by ensuring the incorporation of relatively conservative assumptions in the use of site-specific data. Sites remediated to Tier 1 or Tier 2 are eligible for regulatory closure.

Certain types of site-specific data or assumptions dictate the need for ongoing site management to ensure that the assumptions used to assess human and ecological risks or to develop site-specific objectives remain valid. Ongoing management of a site, or of the contaminants present, will invoke a land use restriction or condition that will preclude regulatory closure. Therefore site-specific adjustments or assumptions that would trigger ongoing management requirements can only be implemented under the Exposure Control option.

To avoid the need for ongoing management and, hence, possible conditions and land use restrictions, Tier 2 adjustments are usually limited to parameters that are measurable and stable, such as soil properties, geological conditions, hydrogeology and distances to natural surface water bodies.

Tier 2 assessments that involve full site-specific risk assessment using models and assumptions that may differ from those used in the calculation of the Tier 1 guidelines may be accepted provided they do not require re-evaluation of generic receptor assumptions from Tier 1 or any form of ongoing risk management. Parameters that are unique to current site use, an existing development or the location of a receptor, such as the characteristics of a site building or the distance to a water well, may change in the future thereby invalidating the site-specific assumptions. An adjustment of such parameters is not allowed at Tier 2.

In some cases exposure pathways may be inoperative under a particular site use (e.g. direct human or ecological contact with contaminated soil at a commercial site that is paved or capped) or the frequency of exposure may differ from the generic assumptions. Preservation of these conditions would require ongoing management; therefore these adjustments cannot be made at Tier 2. Further guidance on parameters and assumptions eligible for adjustment at Tier 2 is provided in Section 4 and Part B of this document. Further guidance on the exposure control option is available in the *Alberta Exposure Control Guide* (AEP, 2016b) and *Risk Management Plan Guide* (AEP, 2017b).

4. Overview of Tier 2 Management

Management under the Tier 2 approach involves modifying Tier 1 remediation guidelines while preserving equivalent human health and ecological protection endpoints. The process for developing, assessing and implementing Tier 1 soil and groundwater remediation guidelines is described in detail in the companion Alberta Tier 1.

The process for Tier 2 management at contaminated sites in Alberta is illustrated schematically in the central portion of Figure 1 and in Figure 3.

Tier 2 remediation guidelines may be derived where adjustments to Tier 1 can be made using exclusion of certain pathways or where parameters or models are simple and based on stable, measured site-specific physical parameters. The pathway exclusion and guideline adjustment options are collectively referred to as Guideline Adjustment in Figure 3. Technical requirements for Tier 2 Guideline Adjustment under these 2 options are provided in Part B and the Appendices to this document.

Complex sites or more complex monitoring situations where measured parameters are not stable or readily determined generally require site-specific ecological or human health risk assessment to develop appropriate Tier 2 remediation objectives. This approach falls under the Site-Specific Risk Assessment (SSRA) category. Part B of this document provides basic guidance for Tier 2 SSRA. Detailed technical requirements for Tier 2 SSRA are beyond the scope of this guidance document. For more information see the Alberta SSRA Guide (GOA, 2022b). Proponents opting for Tier 2 SSRA should contact the regulator to discuss the proposal and to establish the necessary regulatory requirements in these site-specific instances.

4.1 Conditions Triggering Tier 2

The use of Tier 1 guidelines is precluded when site-specific land and/or water use does not conform to a generic land or water use category, when site-specific factors invalidate the modeling used in the derivation of the generic guidelines, when a higher degree of exposure than considered in the generic scenario could result in more stringent guidelines, or when receptors may be more sensitive than considered in the default scenario and therefore result in more stringent guidelines. More detail on these exceptions are provided in the companion Tier 1. They are summarized as follows:

- Source of volatile contaminants present within 30 cm of a building foundation
- Unique building features, including earthen floors or unusually low air exchange rates
- Sensitive receptors that are present but not accounted for in the Tier 1 land use description
- Groundwater flow to stagnant water bodies
- Soil or groundwater contamination present within 10 m of a surface water body
- Very coarse textured materials enhancing groundwater or vapor transport
- Contamination in fractured bedrock
- Contaminant source length parallel to groundwater flow greater than 10 meters
- Organic soils

The assumptions used to derive the generic guidelines may also be conservative relative to site-specific conditions, such that less stringent guidelines could be developed based on site-specific assumptions without reducing the level of human health and environmental protection.

For conditions that require Tier 2 SSRA or Exposure Control options see:

- Alberta SSRA Guide (GOA, 2022b)
- *Alberta Exposure Control Guide* (AEP, 2016b)
- *Alberta Risk Management Plan Guide*. (AEP, 2017b)

Where modifications result in a requirement for land or water use restrictions or where administrative or physical controls are required to meet protection objectives, these are considered under “Exposure Control” as noted in Figures 3 and 4. This option is not eligible for regulatory closure.

4.2 Eligible Exposure Pathway/Receptor and Parameter Modifications for Tier 2

4.2.1 Pathways and Receptor Exclusion

For some specific substances of concern, there are separate Tier 1 Guidelines that have been developed for subsoil and surface soil. For these substances, Tier 1 Guidelines may be applied to the subsoil provided the site meets the requirements as outlined in the companion Alberta Tier 1. See Tier 1 for more detail on the availability and application of the subsoil guidelines.

Certain exposure pathways or pathway-receptor combinations may be excluded at Tier 2 if they are not operative at a given site and their exclusion does not lead to a requirement for land and/or water use restrictions. This document further details where pathways and receptors may be excluded.

A number of exposure pathways are mandatory and are therefore ineligible for exclusion at Tier 2. Where the pathway/receptor is not specifically documented in this guideline, it must always be considered mandatory.

Exposure pathways for potable water, surface water supporting aquatic ecosystems and surface water used for wildlife watering may be excluded if not applicable. Details for these exclusions are provided in Part B, Section 6. For all applications, potential for future use of a surface water body must be considered regardless of current use. Similarly, where an aquifer is defined as a Domestic Use Aquifer or can be used for irrigation in agricultural land, the Tier 1 guideline for groundwater applies at any point in the aquifer, regardless of current water use. Suitability of an aquifer for domestic use is based on the properties of the aquifer and defined below in Part A, Section 2.2 and Appendix E.

For agricultural land use, shallow groundwater may be intercepted by dugouts or surface water that may be used for irrigation or livestock watering. Therefore removal of these pathways is generally considered Exposure Control due to potential for future development. Exceptions may be available for contaminated soil or groundwater that is deeper than surficial excavations for these purposes. In this instance, demonstration that the aquifer is not suitable for irrigation or livestock watering or that there is an isolating unit between the base of the contaminant and the aquifer of concern can be used to rule out this pathway. These exceptions are considered under the Tier 2 site-specific risk assessment option.

4.2.2 Guideline Adjustment

The Tier 1 guidelines that are derived on the basis of fate and transport modeling may be modified where appropriate by the substitution of site-specific values for certain measurable and stable parameters (referred to as Tier 2 Guideline Adjustment). Tier 2 Guideline Adjustment is based on the use of clearly defined chemical fate and transport models used to develop the Tier 1 guideline for the contaminant of concern. Therefore, parameter adjustment at this level is currently only available for the vapour inhalation and groundwater protection pathways. For more detail, see Part B of this document.

The use of site-specific parameters for Tier 2 Guideline Adjustment must be supported by adequate site data justifying the selection of the values used. Use of site-specific parameters must also be supported by measurements from the appropriate depth and locations that are representative of the requirements imposed by the chemical fate and transport model and must be shown to reasonably capture potential spatial and temporal variation of the parameter at the site. If variable, the parameter chosen for substitution in the model must be a conservative estimate based on the distribution in values observed for the site. Use of mean values do not generally lead to conservative estimates and are not acceptable model inputs.

The decision to undertake Tier 2 adjustments is a commitment to increase the “realism” or accuracy of the modeling. Therefore the commitment must also be made to ensure an increased certainty in the level of environmental protection offered by the Tier 2 evaluation. Where the effect of an adjustment in one or more parameters is a

decrease in the calculated guideline value, the lower site-specific value must be used rather than the Tier 1 guidelines. Where measurements are highly variable or uncertain or where insufficient data is available to reliably predict the parameter, the Tier 2 option is not available. Parameters for which site-specific values may be used are discussed in detail in Part B.

4.3 Exposure Pathway or Point-of-Exposure Measurements

Exposure pathway or point-of-exposure measurements of contaminant concentrations, if substituted for predicted values in the fate and transport models used to derive the Tier 1 guideline values, may be used to increase the realism of the modeling and potentially allow relaxation of the Tier 1 value. Examples of such measurements include soil vapour concentrations, groundwater concentrations measured at points between the contaminant source and the identified receptor location, or direct ecological toxicity testing where standard protocols and references have been defined in other guidance supplied by Alberta Environment and Parks.

Due to the potential for large variability in measuring exposure pathway or point-of-exposure concentrations, this option is considered to be Tier 2 SSRA. This document provides some general guidance on the SSRA option and pathways and parameters that are eligible for SSRA. Detailed guidance is beyond the scope of this document. See Part A. Section 5, Appendix D and Alberta SSRA Guide (GOA, 2022b) for further guidance on the SSRA option.

4.4 Tier 2 Assessment and Evaluation

The implementation of the Tier 2 approach is illustrated schematically in Figure 3. The steps in the process are described briefly below and further details are provided in Part B and the Appendices.

4.4.1 Additional Data Collection

Upon entering Tier 2, the proponent will have undertaken an assessment that fulfils the requirements for Tier 1 and provides sufficient information to support the decision to proceed to Tier 2.

Use of Tier 2 always involves more information to support the Tier 2 decision than Tier 1. If Tier 2 adjustments are limited to the exclusion of certain eligible pathways that are inoperative on a site-specific basis, additional site data may be restricted to demonstrating that a particular exposure pathway/receptor is not applicable to the site in question. For instance, exclusion of the drinking water requires demonstration that the aquifer does not fit the definition of a DUA or that there is a natural geologic barrier between the DUA and the impacted aquifer, but would not necessarily require other types of data collection for the site that would not be required for Tier 1.

If Tier 2 involves the recalculation of Tier 1 guidelines based on site-specific parameters, sufficient data must be obtained to ensure the reliable determination of the applicable parameter values. The required data will depend on the governing exposure pathway that is to be modified.

The decision to undertake Tier 2 adjustments requires a commitment to increase the accuracy of the exposure and risk estimates. Therefore, site-specific data must include the measurement of *all* readily quantifiable parameters that are influential with respect to the governing pathway, particularly where one parameter tends to either correlate with or influence the value of another parameter in practice. Site-specific data may include: physical soil properties such as texture, organic carbon fraction, porosity and moisture content; hydrogeological conditions such as depth to groundwater, hydraulic conductivity and hydraulic gradient; depth to contamination; and distance to fixed receptors such as surface water bodies.

4.4.2 Recalculation of Objectives Based on Site-Specific Parameters

Once site-specific parameters have been determined and the applicability of the Tier 2 approach for the subject site and governing exposure pathway(s) has been verified, Tier 2 soil and/or groundwater objectives are calculated using the Tier 1 modeling methods and the site-specific parameter values. Details of the calculation methods are provided in Part B and the Appendices.

4.5 Tier 2 Decision and Management

The Tier 2 decision process is illustrated in the lower part of Figure 3. Initially, the measured contaminant concentrations are compared with the adjusted Tier 2 objectives. If no exceedances are found at this point, and

contaminant sources have been removed, the site can be considered to be in compliance with Tier 2 and no further action is required. Compliance with Tier 2 will lead to regulatory closure.

Where the modified Tier 2 guideline appears to be over-protective, the proponent has the option of moving to a more detailed Tier 2 SSRA option. However, this option will require more ongoing monitoring, and rigorous data requirements to support decision making.

Where soil and/or groundwater conditions exceed Tier 2 objectives, implementation of Tier 2 will involve the development of a remediation plan and the remediation of soil and groundwater to achieve the Tier 2 objective.

5. Overview of Tier 2 Site-Specific Risk Assessment Options

The main purpose of this section of the guidance is to provide a brief overview of the principles of site-specific risk assessment for the Tier 2 approach and discuss situations that would lead to the implementation of this option. A detailed guidance on how to conduct a Tier 2 site-specific risk assessment is beyond the scope of this guideline. See Alberta SSRA Guide (GOA, 2022b) for more information.

Management involving more detailed site-specific risk assessment and the application of site-specific remediation objectives (i.e. Tier 2 SSRA) may be available under Tier 2 and therefore is available for regulatory closure. Where the management plan requires administrative or physical controls to assure that ecological and human receptors are protected, sites will not be available for regulatory closure until the final Tier 1 or Tier 2 risk-based objectives have been achieved and the need for controls is no longer required.

In all instances, site-specific remediation objectives will require use of procedures, protocols, and monitoring that are acceptable to Alberta Environment and Parks. Where there are no clear guidance documents that have been accepted by Alberta Environment and Parks, contact the regulator. Further discussion with the regulator regarding acceptable options and acceptance by the Director will be necessary prior to acceptance of final Tier 2 SSRA remediation objectives.

5.1 Conditions Triggering Site-specific Risk Assessment

Like other Tier 2 options, SSRA involves re-evaluation of exposure pathways. Toxicity reference values are listed in Tier 1 and are not open for readjustment at Tier 2. For more information on toxicity reference values see Alberta TRV guidance (AEP, 2017a).

Situations giving rise to Tier 2 SSRA include:

- Physical site conditions that violate Tier 1 model assumptions, necessitating the use of alternate modeling procedures.
- Land or water uses not covered by the generic land and water use categories, and which cannot be addressed at Tier 2 by the addition or unconditional exclusion of exposure pathways (including the presence of unique exposure conditions or more sensitive receptors).
- Adjustments to site-specific parameters that are not readily measured or verified, or that are not fixed or stable.
- Development of site-specific objectives for direct exposure pathways (e.g. ecological soil contact).

Adjustment of objectives and/or modeling on the basis of exposure pathway or point-of-exposure measurements of contaminant concentrations (e.g. developing soil or groundwater Tier 2 SSRA guidelines by monitoring soil vapour concentrations of a certain volatile organic compound).

5.2 Basis and Considerations for SSRA

5.2.1 Pathways and Receptors

Tier 2 SSRA may be required to consider additional receptors and exposure pathways on a site-specific basis beyond those prescribed under the generic Tier 1 land and water use scenarios.

Receptors and exposure pathways may also be excluded using site-specific risk assessment. However, where the exclusion leads to a requirement for ongoing management or land and/or water restrictions, Tier 2 regulatory closure is not available. For example, excluding a child receptor from a commercial site leads to ongoing access restrictions that limit the use of that land.

5.2.2 Parameters

Development of site-specific remediation objectives may include parameters or models that are beyond the scope of this document.

The SSRA approach will require validation of any risk assessment supported by additional site-specific data to demonstrate that the site condition meets the protection objectives. Where information collected can demonstrate with sufficient confidence that the protection goals required have been achieved, regulatory closure may be available. See the Alberta SSRA Guide (GOA, 2022b) for more information on requirements for this option.

5.2.3 Human Health and Ecological Protection Endpoints

Human health and ecological protection endpoints must be maintained in keeping with Alberta Environment and Parks requirement for the same level of human and ecological protection at all tiers of management. Modification of endpoints requires some form of on-site restrictions or management options. These are considered Exposure Control and therefore are not eligible for regulatory closure.

The procedure under SSRA is generally different than that of other options described in Tier 1 or in this document. SSRA cannot be used to derive guidelines for protection endpoints of a critical receptor. Rather, the approach is to establish whether a fixed level of protection has been achieved for the receptor at risk given the current on-site conditions. For instance, soil vapour monitoring or direct ecological testing might be available to demonstrate that the human or ecological receptor is protected given the current conditions at the site, but may not be able to demonstrate the necessary protection for the range of possible uses under the current zoning.

For more information see the Alberta SSRA Guide (GOA, 2022b).

5.2.4 Alternative Fate & Transport and Exposure Models

There may be cases where there is a requirement to employ chemical fate and transport or exposure models that are different from Tier 1 due to situations where Tier 1 generic guidelines may not apply. It may also be possible to develop a site-specific remediation guideline based on alternative modeling protocols. In these instances, there will be a need for additional monitoring and data collection to verify model assumptions. This approach will require additional interaction with the regulator to verify that the modelling approach and monitoring are sufficient to validate the modelling results. For more information, consult the Alberta SSRA Guide (GOA, 2022b).

5.3 Implementation of Site-specific Remediation Objectives

5.3.1 Data Requirements

The information required to conduct an SSRA must include sufficient site and contaminant characterization, data pertinent to fate and transport modeling, receptor characteristics, toxicity information and other information needed to permit the site-specific quantification of risk and establishment of remediation objectives.

The SSRA involves requirements for information that may vary both spatially and temporally. Information must be comprehensive enough to fully demonstrate the spatial and temporal variations that may be involved. Use of the SSRA approach will require monitoring, often coupled with more detailed modeling procedures, for a sufficient period of time to demonstrate that protection objectives are met and model predictions will continue to correlate with residual concentrations in the future. The variability of parameters leads to some uncertainty in predictions. Therefore as part of the site closure, this approach will require ongoing monitoring often coupled with more detailed modeling procedures to demonstrate how measurements will continue to correlate with contaminant concentration given potential for temporal and spatial variability at the site.

The data collection required for SSRA will depend on the critical exposure pathways and receptors and the availability and applicability of relevant data from other sources for aspects such as toxicity. Provision of a detailed protocol for data collection is beyond the scope of this document but the proponent should be guided by the need to ascertain with a reasonable level of confidence the following:

- nature, degree and extent of contamination
- physical, chemical and hydrogeological characteristics of site soil and groundwater
- building characteristics, if applicable
- human and ecological receptors and their associated exposure factors. In both instances the choice of receptors must consider the need for preservation of the entire range of human or ecological function within

the given land use category. It may therefore be necessary to develop a complete inventory of potential human and ecological receptors that may be important to a site prior to determination of the critical sensitive receptors.

- receptor-specific toxicity information which, in the case of ecological receptors, may require toxicity testing and, at more detailed levels of ecological risk assessment, tissue sampling and analysis.

SSRA will require some form of monitoring to verify predictions. Therefore, data collection must also provide sufficient information to serve as a baseline for long term monitoring of relevant parameters. More information on this option is provided in the Alberta SSRA Guide (GOA, 2022b).

5.3.2 Principles of Site-Specific Risk Assessment

The user is referred to the Alberta SSRA Guide (GOA, 2022b) for more detailed information on human health and ecological risk assessment required for implementation of the SSRA option. The basic steps involved in risk assessment are summarized below.

Where specific guidance is not available from Alberta Environment and Parks, it is up to the user to verify that methods used will be acceptable to Alberta Environment and Parks prior to proceeding.

Problem Formulation

Problem formulation includes identifying the contaminants of concern, the human and ecological receptors and the potential those receptors can become exposed to the contaminants. Complete exposure pathways require a mechanism of chemical release to the transport medium, a transport pathway from the contaminant source to the receptor, and a route of intake at the receptor location. Incomplete pathways may be eliminated on a site-specific basis at this stage, and the complete or potentially complete pathways are incorporated into a conceptual model of the site, which serves as the basis for the subsequent steps of the assessment.

Where regulatory closure is desired, the user will need to assess *potentially* available pathways and receptors. Where incomplete exposure pathways rely on physical or administrative controls (for example, barriers, caps, or land use restrictions that limit receptor exposure, etc.), these are considered forms of Exposure Control and are not eligible under the Tier 2 remediation guideline closure option. Additionally, the absence of certain structures, receptors, or uses at a site where there is potential for their presence cannot be used to support a decision for eliminating exposure pathways under the Tier 2 option. To do so is considered a form of Exposure Control. For Tier 2, all potential uses and receptors must be considered to be present at the site regardless of the current site inventory.

For more information on the Exposure Control option, see the *Alberta Exposure Control Guide* (AEP, 2016b) and *Alberta Risk Management Plan Guide* (AEP, 2017b).

Exceptions are provided for natural geologic barriers under the DUA exclusion option (Appendix E).

Toxicity Assessment/Hazard Assessment

The toxicity assessment or hazard assessment comprises the establishment of either a dose-response relationship or a toxicological or effects-based endpoint value for each contaminant of concern. Toxicity reference values and reference concentrations used to develop the Alberta Tier 1 guidelines are included in the companion Tier 1. In keeping with Alberta Environment and Parks requirement for the same level of human and ecological protection at all tiers of contaminated site management, these reference values must be maintained.

Toxicity Reference Values (TRV) are selected in accordance with *Guidance for Selecting Toxicity Reference Values for Alberta Tier 1 and Tier 2 Soil and Groundwater Remediation Guidelines* (AEP, 2017a). Where the TRV is available for Alberta Tier 1, this must be adopted directly. Where no TRV is available, the procedure outlined in the TRV Guide (AEP, 2017b) must be followed. Where published literature differs, choice of toxicity reference values are subject to review and acceptance by Alberta Environment and Parks. For more information, see Alberta TRV Guide (AEP, 2017a) and Alberta SSRA Guide (GOA, 2022b).

In the case of ecological risk assessment, due to the wide variety of potential receptors, published effects-based data are usually only available for limited test species. Ecological toxicity values that have been developed or adopted for the Alberta Tier 1 guidelines are required as the first source of information for toxicity reference values applied to ecological risk assessment for Alberta. Where no Alberta specific values are available, the procedures for selecting and utilizing published data to develop threshold effects doses or guidelines for various receptors are the same as outlined in the Alberta TRV Guide. For site-specific and receptor-specific ecological risk assessment, it may be necessary to supplement such values through additional literature review and toxicity testing. For more information see the Alberta TRV Guide (AEP, 2017a) and Alberta SSRA Guide (GOA, 2022b).

There is a limited ability to redevelop toxicity reference values for site-specific conditions where there are clear receptors of concern and effects may be based on site-specific conditions. This option will require direct ecological toxicity testing and is based on available protocols as accepted and defined for the substances of concern by Alberta Environment and Parks. See the Alberta SSRA Guide (GOA, 2022b) for more information. The user should consult Alberta Environment and Parks if direct ecological toxicity testing is proposed.

Where no toxicity reference values exist for a given ecological receptor, the user may be required to develop a toxicity reference value as per protocols outlined in CCME (2006a) and based on direct toxicity testing procedures.

Exposure Assessment

Exposure assessment defines the relationship between the contaminant concentration at the source and the exposure or intake at the receptor location, considering both the fate and transport of the contaminant and the behavioral characteristics of the receptor. For direct pathways, exposure assessment involves determining the intake as a direct function of the source concentration to which the receptor is exposed. For indirect pathways the exposure assessment normally involves modeling of the fate and transport mechanisms, including cross-media partitioning of the substance into soil, air or water.

Point-of-exposure measurements may be used to reduce the level of uncertainty in the modeling. However, this approach requires ongoing monitoring and more detailed modeling procedures to demonstrate how measurements will continue to correlate with the contaminant concentration given potential for temporal and spatial variability at the site. Therefore, the majority of site-specific risk assessments will require an ongoing monitoring plan to support a Tier 2 remediation objective.

The methods used in the derivation of the Alberta Tier 1 guidelines are described in the companion Tier 1 and are summarized in Appendix A. Data on receptor characteristics for the Canadian population are described in Tier 1 and must be applied as default parameters where site-specific data does not warrant deviation from general Tier 1 assumptions in Alberta. For more information, see Alberta SSRA Guide (GOA, 2022b).

Risk Characterization

Risk characterization consists of combining the estimated exposure intakes of the contaminants of concern, with the established toxicity data to obtain an estimate of risk. For threshold compounds, human health risk is expressed in terms of hazard index; risk for non-threshold compounds are presented as a lifetime incremental cancer risk. Ecological risk is commonly expressed as an exposure ratio, analogous to a hazard index. If assumptions in the risk assessment are sufficiently conservative, then hazard indices or exposure ratios of less than unity, based on all sources of exposure, signify negligible potential for adverse effect.

For human health, Alberta has established allocation factors to ensure that the total exposure to a chemical of potential concern is not completely allocated to the contaminated site in question, allowing for exposure from other routes not associated with the site in question. These allocation factors are listed in Tier 1 and must be maintained for the site in question.

As part of the risk characterization process, the established relationships between source concentration and risk are used to back-calculate source concentrations corresponding to target risk levels. In this way site-specific risk-based remediation objectives are established for each pathway and receptor. The critical exposure pathway is identified on the basis of the lowest applicable objective, which then becomes the governing objective for the site.

A SSRA will be carried out using deterministic methods and will be based on conservative assumptions about the characteristics of receptors and critical pathways. Deterministic methods have been used in the development of the Tier 1 values, and are implicit in the Tier 2 adjustment procedures.

The use of probabilistic methods is becoming an increasingly common practice in Canada for SSRA, particularly for human health. Probabilistic methods provide a consistent and defensible method of accounting for uncertainty and natural variability in key assumptions such as site conditions and receptor characteristics. The use of probabilistic methods, however, are subject to a reduced level of transparency and reproducibility. Therefore, although probabilistic risk assessment provides insight that can facilitate risk management decision from the standpoint of level of protection or conservatism, the approach will not support an application for regulatory closure under Tier 2.

5.4 Identification of Conditions/Restrictions Associated with Site-Specific Risk Assessment

As noted previously, SSRA may permit regulatory closure, provided the site-specific data are adequate, the parameters utilized in the risk assessment are fixed and stable, and the exposure conditions assumed are at least as protective as the default assumptions used at Tier 1 and Tier 2. This will, however, result in some need for ongoing monitoring and/or validation of assumptions. Therefore, SSRA will require a monitoring plan as part of the risk assessment until stable endpoints can be demonstrated. Generally, this form of risk assessment cannot be used to develop risk-based guidelines but may be applied to establish the potential for risk associated with the presence of a residual contaminant under the set of site-specific conditions at a given site.

Regulatory closure is not available if the site-specific conditions require ongoing Exposure Control to limit risk to critical receptors or ongoing monitoring to validate those risks. Therefore if land or water use restrictions are implicit or explicit in the exposure assumptions and/or if residual contaminant concentrations are associated with unacceptable levels of risk to receptors the site will require Exposure Control. See the *Alberta Exposure Control Guide* (AEP, 2016b) and *Alberta Risk Management Plan Guide* (AEP, 2017b) for more information.

5.5 Site-Specific Risk Assessment for Salt Contaminated Soil

Alberta's Tier 1 guidelines for salt-contaminated soil are based on impacts to vegetation and were not developed using the models described in Appendix C. Salinity-specific approaches are required for the development of Tier 2 guidelines for salt-contaminated sites. Within Alberta's Framework, the Subsoil Salinity Tool provides Tier 2 options for remediation of chloride-based salinity below the root zone (nominally 1.5 metres). The Subsoil Salinity Tool is a software program that uses site-specific information to estimate transport of chloride to a Domestic Use Aquifer, surface water bodies and upward into the root zone. The software and accompanying information are available on the Alberta Environment and Parks website.

6. Exposure Control

Exposure Control includes site management measures designed and implemented to ensure that exposures do not result in human and ecological risks in excess of levels considered acceptable. The role of exposure control in the control of risk at contaminated sites is captured in Figures 1 to 3. Figure 4 provides more information on how exposure control is implemented.

Exposure Control is required when contamination exceeds Tier 1 or Tier 2 remediation guidelines where measures to preserve the site conditions or exposure assumptions are required to obtain acceptable risk levels, or otherwise to limit exposure to acceptable levels. Conditions that give rise to exposure control include but are not limited to:

- Adjustments to site-specific parameters or exposure pathways/receptors that require management or control measures.
- Adjustments to site-specific parameters or exclusion of pathways that result in conditions or restrictions on land and/or water use.
- Practical or economic limitations to feasibility of remediating to Tier 1 or Tier 2 objectives
- Decision to implement long-term risk management (e.g. in association with long-term remediation, or at an operating facility).

The *Alberta Exposure Control Guide* (AEP, 2016b) outlines the circumstances under which Exposure Control may be an acceptable option and provides the minimum requirements for managing a site under Exposure Control. Guidance for developing risk management plans in support of Exposure Control is provided in the *Alberta Risk Management Plan Guide* (AEP, 2017b).

Part B: User Guidance for Tier 2 Management

1. Introduction

Part A of this guideline provides an overview of the framework for managing contaminated sites in Alberta and the stages and decision points for proceeding through the tiered system. Part B provides more detailed guidance on Tier 2 options in general and prescriptive guidance for implementing Tier 2 Guideline Adjustment and Pathway Exclusion options.

The general information will apply to the Tier 2 Site-Specific Risk Assessment option as well. However, a detailed description is beyond the scope of this document. For more detailed guidance on Tier 2 Site-Specific Risk Assessment, see the Alberta SSRA Guide (GOA, 2022b).

The relationship of Tier 2 to other options in the management framework is illustrated in Figure 1 and the Tier 2 process is shown schematically in the flow chart presented in Figure 3.

2. Conditions Where Tier 2 is Required

The use of Tier 1 guidelines may be precluded by site-specific factors that invalidate the modeling used in the derivation of the generic guidelines or result in a higher degree of exposure than that considered in the generic exposure scenario. These exceptions are explained in more detail in the companion Tier 1. They include:

- Source of volatile contaminants present within 30 cm of a building foundation
- Unique building features, including earthen floors or unusually low air exchange rates
- Sensitive receptors that are present but not accounted for in the generic Tier 1 land use description
- Groundwater flow to stagnant water bodies
- Soil or groundwater contamination present within 10 m of a surface water body
- Very coarse textured materials enhancing groundwater or vapor transport
- Contamination in fractured bedrock
- Contaminant source length parallel to groundwater flow greater than 10 meters
- Organic soils

If any of these conditions exist at the site, a Tier 2 approach must be taken to determine whether the level of protection afforded by the Tier 1 guideline is protective or whether the Tier 1 guidelines must be lowered to account for the risk associated with the site-specific conditions.

Specific conditions under which the Tier 1 values are not valid are listed in Table 1. Situations where site conditions may give rise to higher degrees of exposure are also summarized in Table 1. Further guidance may be obtained by comparing site-specific parameters with the default Tier 1 assumptions presented in Appendix A.

If the above situations can be accounted for by the site-specific adjustment of relevant parameters, or inclusion of more sensitive receptors or exposure scenarios, the approach outlined here can be used. However, if alternative modeling approaches are required, this would necessitate proceeding to Tier 2 SSRA. Where a site-specific condition is expected to result in exposure risks greater than those used in conservative Tier 1 assumptions, or where the critical receptor may be at greater risk than in the generic condition, site-specific risk assessment to determine risk to the critical receptor must always be undertaken.

Where the Tier 2 Risk Assessment leads to assurance that receptors are still protected at the generic level, the generic guidelines may still be used.

3. Conditions Precluding Implementation of Tier 2

Although a number of site-specific factors may mitigate exposure to human and ecological receptors, not all can be considered in the changes to model derivation. The preceding section identified some general criteria for assessing the potential for simple model manipulations. Based on these and other considerations, certain site-specific conditions would preclude the implementation of Tier 2 at a given site. In particular, any condition requiring land or water use restrictions would not be considered for Tier 2 modification. Conditions precluding the use of specific model changes, or which cannot be directly incorporated into the models described here, include the following:

- Modified receptor characteristics and exposure frequencies/durations, except where these address more sensitive receptors or greater degrees of exposure than those associated with the Tier 1 land or water use category
- Modified site-specific parameters or assumptions that require administrative or institutional controls in order to remain valid
- Exclusion of exposure pathways that may become operative in future under a particular land use category, or that requires management to ensure they remain inoperative. Where potential exists for development where a receptor may become present in the future or where an exposure pathway may become developed in the future, that must be considered in the development of the guidelines regardless of current land use.
- Modifications based on point-of-exposure or exposure pathway measurements. Modifications may be allowed at the Tier 2 SSRA level with the appropriate supporting information, but is not considered Tier 2 Guideline Adjustment. Alberta Environment and Parks should be consulted for Tier 2 modifications based on exposure pathway or point-of-exposure measurements.
- Modifications or exclusions that lead to any land or water use restriction.
- Site-specific properties that are not accounted for in the generic models, as described in Appendix C, Section C.7.

Where Tier 2 Guideline Adjustment or Site Specific Risk Assessment is not available for the critical exposure pathway, then the Tier 1 remediation guidelines must be adopted. Exposure control options may still be available subject to other conditions described in this document and the *Alberta Exposure Control Guide* (AEP, 2016b) and *Alberta Risk Management Plan Guide* (AEP, 2017b).

4. Tier 2 Options for Specific Exposure Pathways and Receptors

Tier 1 remediation guidelines have been developed for soil and groundwater, for a number of pathways under which a receptor could potentially become exposed. Under Tier 1 management, each exposure pathway is considered to be operative, and the associated Tier 1 guideline value is based on the default assumptions and parameters that represent generic exposure scenarios associated with the respective land and water use definitions. The exposure pathways and receptors considered under each land use are presented in Table 2; the general chemical properties for which the defined human health and ecological exposure pathways apply are shown in Tables 3 and 4.

At Tier 2, certain exposure pathways may be considered to be inoperative, or assumptions and parameters that govern exposure may be adjusted based on site-specific information. The eligibility for exclusion of a pathway or adjustment of a guideline value at Tier 2 is a function of the pathway. Specific exposure pathways or pathway-receptor combinations and eligibility for development of a Tier 2 remediation guideline through pathway exclusion or pathway modification are discussed below. Table 5 summarizes allowable exclusions and modifications.

4.1 Direct Human Contact with Soil

Direct human contact with soil is not available for site-specific exclusion or modification at Tier 2.

Direct human contact with soil includes soil ingestion, dermal contact and inhalation of soil particulate. The degree of exposure through direct contact is primarily related to characteristics of the receptor, therefore, site-specific factors

are not readily accounted for in determining the soil guideline value. Direct soil contact is considered operative for all Tier 2 scenarios. Although direct human contact with soil may be avoided through exposure control, for example, where the soil is paved or capped and therefore inaccessible, or where contamination is present at depth, these require ongoing management measures to maintain the condition.

4.2 Human Vapour Inhalation

Human vapour inhalation is considered to be operative in all cases at Tier 2, except in natural areas, but guideline values may be modified at the Tier 2 Guideline Adjustment level by substitution of certain site-specific parameters. Site-specific risk assessment of the vapour pathway may be possible but must consider the potential for building development anywhere on the site.

Inhalation of volatile contaminant vapours migrating into buildings applies in the case of volatile contaminants in situations where a building is or may be present. Since buildings may be present under all land use categories except natural areas, the vapour inhalation pathway cannot be excluded without imposing a land use restriction. Modification of the guideline values based on site-specific building location or configuration also leads to a land use restriction and/or management requirements. The Tier 1 remediation guideline values are derived from the modeling of vapour migration and intrusion, on the basis of a number of site-related parameters. Certain parameters are considered to be fixed and stable and can therefore be adjusted on a site-specific basis without the need for restrictions or management measures.

4.3 Ingestion of Produce, Meat and Milk

Ingestion of produce, meat and milk is not eligible for Tier 2 Guideline Adjustment. It is considered to be operative under all agricultural and residential land use but may be excluded in a very narrow range of residential/parkland settings where backyard produce is excluded due to land use zoning and the pathway does not have potential to become a controlling pathway. Ingestion of produce, meat and milk must be considered for Tier 2 SSRA on agricultural and residential land use.

Ingestion of produce, meat and milk applies for all substances, but becomes particularly critical for substances that bioaccumulate, under agricultural and residential/parkland land uses. More specific guidance on assessment of substances that may bioaccumulate or biomagnify may be found in CCME (2006a).

The guideline values are based primarily on receptor characteristics and bioavailability, and therefore cannot be modified at Tier 2. It may be possible to exclude the pathway under very specific residential/parkland conditions where zoning and/or development patterns preclude raising backyard produce, for example in some multi-family residential settings. In this case, it must be demonstrated that zoning is fixed to this land use.

4.4 Protection of Potable Groundwater

The groundwater ingestion pathway may be excluded at Tier 2 where no DUA is present, or where an adequate isolating layer exists between the DUA and zone of contamination. Where the pathway is operative, Tier 2 Guideline Adjustment may be undertaken by substitution of certain site-specific parameters. Site-specific risk assessment may be possible for the groundwater pathway, but must protect drinking water quality at all points within the DUA.

Protection of potable groundwater is applicable in all cases where groundwater is, or has the potential to be used as drinking water. A Domestic Use Aquifer (DUA) has been defined previously in Part A with specific details in Appendix E. This pathway may be excluded at Tier 2 where no DUA is present, or where a DUA exists but an adequate natural geologic barrier is present between the zone of contamination and the DUA. For more information, see Part A and Appendix E. Site-specific stratigraphic information and hydraulic conductivity measurements are required to demonstrate the presence of this isolation barrier.

The derivation of soil guidelines for the protection of potable groundwater is based on a leaching, mixing and dilution model that considers certain soil and hydrogeological parameters. Certain parameters are considered to be fixed and

stable and can therefore be adjusted on a site-specific basis without the need for restrictions or management measures. Tier 2 remediation objectives require drinking water objectives to be met everywhere within the DUA.

Distance to the groundwater user cannot normally be adjusted at Tier 2, since this would imply a restriction on groundwater use within the defined aquifer zone. An exception to this case exists when large diameter (“bored”) wells are completed in geologic units that do not meet the hydraulic conductivity or yield criteria defining a DUA. In this case, the water well can be considered a receptor location and dealt with on a site-specific basis. The goal in this case is to ensure compliance with drinking water guidelines prior to the contaminant reaching the zone of influence of the large diameter well. Acceptance by the regulator is necessary for site-specific approaches in the presence of large diameter bored wells.

4.5 Soil Contact (Plants and Invertebrates)

The soil contact pathway for plants and invertebrates is considered operative in all cases at Tier 2, and is not eligible for site-specific exclusion or Tier 2 Guideline Adjustment except for petroleum hydrocarbons where soil management guidelines exist below 3 m. Tier 2 SSRA by direct ecological toxicity testing may be permissible but is presently restricted to a limited range of contaminants.

Soil contact for plants and invertebrates is considered under all land use categories. Exclusion of this pathway requires ongoing exposure control and therefore is not available at Tier 2. In some instances, there are subsoil guidelines available under the Tier 1 approach that may be based on different ecological considerations. These are noted for salinity and hydrocarbons in the companion Tier 1.

Site-specific factors are not readily accounted for in determining the soil guideline value, with the possible exception of soil type. Therefore, any modification of the guideline value would necessitate site-specific toxicity testing and be considered under SSRA. At present, direct ecological toxicity testing for SSRA is restricted to a few specific compounds (e.g. petroleum hydrocarbons, benzene, toluene, ethylbenzene, xylenes) where toxicity testing protocols are clearly defined and can be replicated in site-specific instances. Most ecological guidelines are either based on limited data sets that are not readily subject to site-specific verification (e.g. PAH guidelines) or more comprehensive data sets that are beyond the scope of most studies (e.g. salt guidelines) and therefore are not available for site-specific verification. Alberta Environment and Parks should be consulted prior to site-specific modifications of this pathway.

4.6 Soil and Food Ingestion by Livestock and Wildlife

The soil and food ingestion pathway must be considered at Tier 2 under all agricultural and natural land use and is not eligible for Tier 2 Guideline Adjustment. SSRA must consider all aspects of potential soil and food ingestion for critical receptors at the site. For substances that bioaccumulate, this exposure pathway may be important on residential, commercial and industrial sites.

Soil and food ingestion by livestock and wildlife is considered to be an operative pathway under agricultural land use; soil and food ingestion by wildlife is operative under the natural area land use. Livestock must also be included as a receptor at natural area sites where grazing leases are in effect. Soil guidelines for soil and food ingestion by livestock and wildlife are not amenable to modification based on site-specific factors. Where this exposure has the potential to be a controlling pathway, particularly where there is potential for bioaccumulation, this pathway will also need to be considered on residential, commercial and industrial sites. See CCME (2006a) for more details.

4.7 Protection of Groundwater for Aquatic Life

Protection of groundwater for aquatic life may be excluded at Tier 2 if no surface water bodies are present within 300 m of the site. If the pathway is operative, certain soil and groundwater parameters are eligible for Tier 2 Guideline Adjustment. Protection of groundwater for aquatic life is eligible for Tier 2 SSRA.

Protection of groundwater for aquatic life must be considered when surface water bodies are present within 300 m of the site. If the direction of groundwater flow has been reliably determined by site-specific groundwater monitoring, this may be limited to 100 m up gradient and 300 m down gradient of the site.

The 300 m radius must be measured from the closest point of the zone of contamination exceeding the aquatic guidelines to closest point of the flood risk area (defined as the nearest distance to the floodway or, where this is not defined, the professional must determine the distance to the flood risk area based on site information (e.g., geologic information, high water mark). This determination must be accepted by the regulator.

In the absence of surface water bodies within the specified distance, this pathway may be excluded at Tier 2.

The soil guideline values for the protection of aquatic life are derived by considering leaching, mixing and dilution, together with advective-dispersive transport over a lateral distance of 10 m. Under the Tier 1 approach, this is assumed to be the minimum typical distance between an operating site or facility and a natural surface water body. Therefore, 10 m represents the minimum separation distance that must be present between the edge of a stable or decreasing plume and the flood risk area of the water body in question for the Tier 1 aquatic guidelines to be applied. Where the site does not meet this condition, it may be necessary to recalculate the Tier 1 objective using a 0 separation distance between the water body and the contaminant.

To use either the 300 m offset for exclusion of aquatic life or the 10 m default for calculation of Tier 1 objectives, the following conditions must be met.

1. Both the 300 m offset for exclusion of aquatic life and the 10 m offset for calculation of Tier 1 guidelines assume a stable or decreasing dissolved contaminant plume. Therefore, application of the offset distance cannot be done before all potential sources have been removed.
2. Where the contaminant is a conservative solute that has little interaction with the soil or geological matrix and has low biodegradation potential (e.g. chloride), the potential for the contaminant to impact the surface water body must be assessed and demonstrated through modeling or monitoring before applying the default distance.
3. Where the Darcy velocity (hydraulic conductivity x hydraulic gradient) is greater than the default value for coarse soils (3×10^{-7} m/s), the use of the 300 m offset for exclusion of groundwater cannot be automatically assumed. In these instances, it must be shown that the site condition is equivalent to or at lower risk than the default scenario at 300 m prior to exclusion of the aquatic life pathway.
4. Where the Darcy velocity is greater than the default for coarse soil or for any coarse textured site located on the flood risk area, the 10 m offset for the calculation of Tier 1 guidelines for aquatic life cannot be automatically used. Tier 2 objectives must be calculated assuming zero separation distance to the aquatic water body, or it must be demonstrated at Tier 2 that the site condition is equivalent to, or at lower risk than, the default scenario for coarse soils prior to applying the Tier 1 aquatic life guidelines.

Options for recalculation of the aquatic pathway or SSRA with respect to the aquatic pathway are available. Certain soil and hydrogeological conditions considered in the modeling are considered to be fixed and stable and can therefore be adjusted on a site-specific basis without the requirement for ongoing management. In addition, the distance to a natural surface water body can also be adjusted to reflect the appropriate site-specific value. SSRA based on direct groundwater measurements is possible and requires a more detailed assessment of groundwater quality, flow direction, velocity, detailed contaminant assessment and modeling.

4.8 Protection of Groundwater for Livestock

Protection of groundwater for livestock must be considered at Tier 2 under agricultural land use and in natural areas with grazing leases unless there is no suitable aquifer beneath the site and the contaminant is below the depth of a typical excavation for a dugout. Certain soil and groundwater parameters are eligible for Tier 2 Guideline Adjustment, and this pathway is eligible for SSRA as long as the entire aquifer is protected.

Ingestion of groundwater through livestock watering is considered an operative pathway under agricultural land use and in natural areas subject to grazing leases. The derivation of soil guidelines for the protection of groundwater for livestock is based on a leaching, mixing and dilution model that considers certain soil and hydrogeological parameters. Due to the potential to develop surficial dugouts for livestock watering, the pathway cannot be automatically ruled out for the agricultural land use. Where contamination is clearly below the depth that would

normally be associated with a surficial dugout and where the underlying groundwater is not suitable for livestock watering, it may be possible to rule the pathway out in the event that there is a similar intervening layer between the contaminated aquifer and any aquifer that may be suitable for livestock watering, as defined for the drinking water aquifer.

Certain parameters are considered to be fixed and stable and can therefore be adjusted on a site-specific basis without the need for restrictions or management measures. Distance to groundwater user cannot be adjusted at Tier 2, since this would imply a restriction on groundwater use within that distance.

4.9 Protection of Groundwater for Irrigation

Protection of groundwater for irrigation must be considered at Tier 2 under agricultural land use unless there is no suitable aquifer beneath the site and the contaminant is below the depth of a typical excavation for a dugout. Certain soil and groundwater parameters are eligible for adjustment at Tier 2. Tier 2 SSRA is possible but it must protect the entire aquifer of concern.

Use of groundwater for irrigation is considered an operative pathway under agricultural land use. The derivation of soil guidelines for the protection of groundwater for irrigation is based on a leaching, mixing and dilution model that considers certain soil and hydrogeological parameters. This pathway is included in all agricultural scenarios. Due to the potential to develop surficial dugouts for irrigation, the pathway cannot be automatically ruled out for the agricultural land use. Where contamination is clearly below the depth that would normally be associated with a surficial dugout and where the underlying groundwater is not suitable for irrigation, it may be possible to rule the pathway out in the event that there is a similar intervening layer between the contaminated aquifer and any aquifer that may be suitable for irrigation, as defined for the drinking water aquifer.

Certain parameters are considered to be fixed and stable and can therefore be adjusted on a site-specific basis without the need for restrictions or management measures. Distance to groundwater user cannot be adjusted at Tier 2, since this would imply a restriction on groundwater use within that distance. Site-specific risk assessment is possible for protection for irrigation but is subject to an increasing level of detail requirements regarding the aquifer dynamics and contaminant characteristics. In addition it must be shown to protect all points within the aquifer of concern.

4.10 Protection of Groundwater for Wildlife

Protection of groundwater for wildlife watering is applicable under natural areas and agricultural land uses, but may be excluded at Tier 2 if no surface water bodies are present within 300 m downgradient of the site. If the pathway is operative, certain soil and groundwater parameters are eligible for Tier 2 Guideline Adjustment. This pathway is also eligible for SSRA.

Ingestion of water by wildlife is considered an operative pathway under the natural areas and agricultural land uses, and must be considered when there are surface water bodies within 300 m of the site. If the direction of groundwater flow has been reliably determined by site-specific groundwater monitoring, this may be limited to 100 m up gradient and 300 m down gradient of the site.

The 300 m radius is measured from the closest point of the zone of contamination to the closest point of the flood risk area (e.g. floodway if defined or high water mark if undefined) of the water body. The use of the 300 m offset distance is subject to the same restrictions as specified for protection of aquatic life. Namely, the user must assess the following prior to applying the offset limit.

1. The dissolved contaminant plume is stable or decreasing (e.g. all potential sources have been managed) and the offset distance does not have the potential to change with time.
2. Where the contaminant is a conservative solute that has little interaction with the soil or geological matrix and has low biodegradation potential, the potential risk for impact to the water body beyond 300 m must be assessed and demonstrated through modeling or monitoring before applying the default distance.

3. The Darcy velocity is no greater than that of the default for coarse soils (3×10^{-7} m/s). Where the Darcy velocity is greater than that of the default, the user may be able to establish an offset distance that is equally protective.

Provided these exceptions do not apply to the site, this pathway may be excluded at Tier 2.

The soil guideline values for the protection of wildlife watering are derived by considering leaching, mixing and dilution, together with advective-dispersive transport over a lateral distance of 10 m, considered to be the minimum typical distance between an operating site or facility and a natural surface water body. Use of the Tier 1 value for wildlife watering is subject to the same exceptions as those specified for the aquatic life guidelines. Therefore, as with the aquatic life guidelines, the user must determine that the following will not apply to the soil or recalculate the guidelines at Tier 2 using a zero offset distance:

1. There is a stable or decreasing plume (e.g. a plume where all potential sources have been managed). The offset distance cannot be applied until this is accomplished
2. Where the Darcy's velocity is greater than the default for coarse soil (3×10^{-7} m/s) or for any coarse textured site located on the flood risk area, the 10 m offset for the calculation of Tier 1 guidelines for wildlife watering cannot be automatically used. Tier 2 objectives must be calculated assuming zero separation distance to the aquatic water body, or it must be demonstrated at Tier 2 that the site condition is equivalent to, or at lower risk than, the default scenario for coarse soils prior to applying the Tier 1 wildlife watering guidelines.

Certain soil and hydrogeological conditions considered in the modeling are considered to be fixed and stable and can therefore be adjusted on a site-specific basis without the requirement for ongoing management. In addition, the distance to a natural surface water body can also be adjusted to reflect the appropriate site-specific value. This adjustment must be made if the surface water body is within 10 m of the site.

4.11 Other Considerations

Tables 2, 3 and 4 summarize the main pathways and receptors that must be considered for all human health and ecological risk assessment. Table 5 summarizes the human and ecological pathways considered at Tier 1, identifying those that are eligible for exclusion or modification at Tier 2. For more information on other considerations not listed here, the user is referred to CCME (2006a). For more information on site specific risk assessments, refer to the Alberta SSRA Guide (GOA, 2022b).

While tables can be used as a guide, they are not an exhaustive list of all pathways and receptors that may be important for site evaluation, particularly where detailed SSRAs are required. In conducting any Tier 2 reassessment, the user must reassess potential for impacts to all pathways and receptors that may be critical to ensure that Tier 2 modifications proposed remain protective of all pathways and receptors.

For detailed site-specific risk assessments, all human health and environmental concerns associated with residual contamination must be met. Where potential risk associated with any other consideration is greater than that of any pathways or receptors listed here, that must be used in setting the risk based cleanup guidance. Some other concerns not specifically addressed in this list that must be considered in conducting any detailed risk assessment include:

1. For environmental receptors, Soil Ingestion by Primary Consumers must be considered on all natural, agricultural and residential sites.
2. For environmental receptors, Soil Ingestion by Secondary and Tertiary Consumers must be considered on all natural, agricultural and residential sites where the contaminant has the potential to biomagnify or bioconcentrate.
3. For environmental receptors, Nutrient and Energy Cycling must be considered on all land uses.
4. For environmental and human health, Offsite Migration potential must be considered for all commercial and industrial sites.

5. For human health, consumption of produce, meat, milk from the contaminated site must be considered for all contaminants that have potential to biomagnify or bioconcentrate.
6. For environmental and human health, where soil and food ingestion is a critical pathway of concern, it must be considered on commercial and industrial properties as well. For more guidance, the user is referred to CCME (2006a).
7. For all human health assessments, risk from subchronic and acute events must be evaluated to determine that the assessment is protective of these events. See CCME (2006a) and the Alberta SSRA Guide (GOA, 2022b) for more information.
8. For all sites where the receptor or the nature of land use may be more sensitive than that used in default scenarios, these must be evaluated and used in determining risk.
9. Considerations of other risks other than direct toxicity must be evaluated in determining contaminant risk. Other considerations include but are not limited to aesthetics, explosive risk, potential for health or environmental risk in the event of excavation, potential for free phase formation, or damage to utilities or infrastructure. Where risks associated with these concerns are greater than for other pathways, the risk must be assessed and appropriate adjustments made to ensure that the contaminant does not pose an ongoing risk.

5. Conditions for Tier 2 Guideline Adjustment

If the default assumptions used in the derivation of the governing Tier 1 values are conservative relative to actual site-specific conditions, the replacement of default assumptions with site-specific data for certain influential parameters may permit the development and implementation of Tier 2 objectives. There may also be some opportunity to use exposure pathway or point-of-exposure measurements to reduce model uncertainty, as dealt with under the site-specific risk assessment category.

Tier 2 adjustments are only likely to be of benefit when applied to parameters that affect the governing exposure pathway. The soil and groundwater remediation guidelines presented in Appendices A and B in the companion Tier 1 can be used to determine the governing pathway for a given chemical, land/water use and soil type. Table B.1 in Appendix B provides some qualitative information on the parameters that are potentially influential on the guidelines for the various governing pathways. The table may be used to assist in a preliminary screening of the opportunity for Tier 2 management. This table is provided as a guide only. The influence of a given parameter may be chemical-specific and dependent on the values of other parameters. Therefore, more detailed procedures as outlined in this section of the guidance and Appendix C is required to assess the magnitude and direction of any potential change.

Tier 2 Guideline Adjustments made here are limited to three principal criteria:

1. They are limited to factors influencing exposure that can be measured and verified.

Guideline Adjustments must relate to stable site characteristics that affect contaminant fate and transport and human and ecological exposure. Examples include physical soil properties, distances to receptor locations (where these can be considered fixed) and, in some cases, form and composition of the contaminant. These characteristics must be readily quantifiable, and their effects on the numerical objectives must be capable of determination without departing from the scientific principles used in the derivation of the Tier 1 standards.

2. They must support clear and consistent land and water use decision making

Guideline Adjustments cannot compromise the generality of the defined land and water uses. If they lead to land or water use restrictions, these must be clearly identified. Adjustments leading to restrictions are not allowed under the Tier 2 approach.

3. They must be simple and straightforward in their determination and application

Part of the philosophy of a multi-tiered system is that each successive tier requires a greater level of investigative effort and a potentially greater degree of regulatory intervention. It is expected that a majority of

sites will be managed using the Tier 1 and Tier 2 Guideline Adjustment approach, and progressively fewer with site-specific risk assessment or exposure control. The goal of the Alberta framework is that both Tier 1 and Tier 2 can be implemented consistently.

Parameters and assumptions that influence the Tier 1 (and hence Tier 2) values and meet the above requirements are listed in Table C-1 of Appendix C and are referred to as primary Tier 2 adjustable parameters.

In addition to the primary parameters, other parameters influence the remediation objectives but do not comply with one or more of the criteria listed above. These are referred to as secondary adjustable parameters. Although some of these may be accommodated in the Tier 2 approach, any that necessitate a land or water use restriction are not presently allowed at Tier 2. At this time, only mixing zone thickness and aquifer thickness, where appropriately supported are allowed in the secondary parameters. There are some specialized cases where horizontal offsets may also be allowed, but these are restricted to:

1. Zoning cases where the contaminant contained on a particular zoning (e.g. commercial, industrial) is being assessed for compliance on a neighbouring, more restrictive land use zone (e.g. residential) or;
2. Cases where the physical structures present on the site are more sensitive than assumed under the Tier 1 guideline development. For instance, where building parameters are more sensitive due poor air exchange rates or presence of an earthen floor basement or where bored wells are present in an aquifer that would not normally be considered a domestic use aquifer (see Appendix E), horizontal offsets to the structure of concern may be employed.

In all other instances, the use of a horizontal offset distance lead to development restrictions that are not available at Tier 2.

Certain exposure pathway or point-of-exposure measurements of contaminant concentrations, if substituted for predicted values in the fate and transport models used to determine the Tier 1 guidelines, may be used as a basis for modifying Tier 1 guidelines. However, this is only available under the Tier 2 SSRA or Exposure control options. For more information see Alberta SSRA Guide (GOA, 2022b), *Alberta Exposure Control Guide* (AEP, 2016b) and *Alberta Risk Management Plan Guide* (AEP, 2017b).

The incorporation of exposure pathway or point-of-exposure measurements will require more thorough verification and long-term monitoring to verify predictions. Concentrations measured at such locations may be a function of time; if measured values are less than predicted values, evidence must be obtained that the values are not likely to increase with time.

6. Eligible Modifications for Tier 2 Guideline Adjustment

6.1 Introduction

When site conditions warrant, Tier 2 Guideline Adjustment is available for exposure pathways and receptors where Tier 1 guidelines were based on clearly defined chemical fate and transport models. The exposure pathways for which this option is presently available at Tier 2 are:

- Indoor vapour inhalation, based on the modeling of migration and intrusion of volatile substances in soil vapour into the indoor air of occupied buildings, and
- Protection of groundwater for
 - aquatic life
 - livestock watering
 - irrigation water
 - wildlife watering, and
 - potable water use

These exposure pathways employ modeling of contaminant leaching, mixing, dilution and, in the case of aquatic life or wildlife watering, lateral advective-dispersive transport in groundwater.

6.2 Parameters

Tier 1 soil remediation guideline values pertaining to certain operative exposure pathways may be modified at Tier 2 by the substitution of site-specific values for adjustable parameters. This option is limited to exposure pathways where the determination of Tier 1 guideline values includes fate and transport modeling.

The key site-specific parameters are summarized in Table 6 for the vapour intrusion pathway and the groundwater pathways. Those parameters that are eligible for adjustment at Tier 2 are indicated in the tables. The tables also indicate whether adjustment of the parameters would lead to land or water use restrictions or a requirement for ongoing management. Land and water use restrictions are not eligible for Tier 2 closure.

The use of site-specific parameters at Tier 2 must be supported by adequate site data justifying the selection of the values used. Furthermore, the decision to undertake Tier 2 adjustments is a commitment to increase the “realism” of the modeling. Therefore, the commitment must also be made to ensure an increased certainty in the level of environmental protection offered by the Tier 2 evaluation. Where the effect of an adjustment in one or more parameters is a decrease in the calculated guideline value, the lower site-specific value must be used rather than Tier 1 guidelines. Where measurements are highly variable or uncertain or where insufficient data is available to reliably predict the parameter, the Tier 2 option is not available. Data collection for Tier 2 adjustments must be relevant to the depth and location that is associated with the use in the model and must be sufficient in scope and numbers to account for typical spatial and temporal variability associated with the parameter. Single measurements can never be used for Tier 2 adjustments as they will not account for potential variability. The model parameter used for the Tier 2 adjustment must always represent a conservative estimate based on the variability of in-field measurements.

6.3 Exposure Pathway or Point-of Exposure Measurements

Certain exposure pathway or point-of-exposure measurements of contaminant concentrations may be used as part of SSRA. In some instances, these modifications may be used in conjunction with models presented herein to improve accuracy of model predictions. Direct exposure pathway measurements requires site-specific risk assessment, including increased data collection, contaminant delineation and long term monitoring requirements that are beyond the scope of this document. Further discussion of the approach, which may be considered under Tier 2 SSRA, is provided in Appendix D and in the Alberta SSRA Guide (GOA, 2022b).

7. Tier 2 Implementation

7.1 Additional Data Collection to Support Site-Specific Adjustment of Parameters

Upon entering Tier 2, the proponent will have undertaken an assessment that fulfils, as a minimum, the basic requirements for Tier 1 and provides sufficient additional information to support the decision to proceed to Tier 2. To complete the Tier 2 evaluation, which essentially comprises the substitution of certain site-specific parameters for Tier 1 default assumptions or the exclusion of exposure pathways which are not active at the site, the relevant adjustable parameters must be determined and adequately quantified, and the relevant exposure pathways must be confirmed.

To optimize data collection effort and resources at this stage, the governing exposure pathways (based on the Tier 1 evaluation) will be identified. Not all Tier 2 adjustable parameters will be influential for every exposure pathway and receptor. Therefore depending upon the critical pathway(s), only a subset of the possible parameters may need to be defined on a site-specific basis. However, if the Tier 2 modifications result in a different pathway becoming the governing exposure pathway or potentially becoming a governing pathway, this must be investigated as well. Where Tier 2 modifications are allowed for this pathway, there may be value in characterizing site parameters relevant to those additional exposure pathways.

The decision to undertake Tier 2 adjustments implies a commitment to increase the accuracy of the exposure and risk estimates in light of the available site-specific data. Therefore, the values of all readily quantifiable parameters that are influential with respect to the governing pathway must be determined and applied.

Table 6 summarizes parameters governing the vapour inhalation and groundwater protection pathways, indicating those that can be adjusted at Tier 2. Certain groups of parameters (e.g. soil properties, hydrogeological, parameters etc.) are related and must be measured and adjusted together as a group. Groups of parameters, together with the exposure pathways to which they relate, are given in Table C-2, Appendix C.

Further discussion of the parameters and their recommended method of determination is presented in Appendix C. Some considerations regarding the determination of these parameters are presented below.

7.1.1 Physical Soil Properties

These properties include soil texture, organic carbon fraction, soil porosity and/or bulk density and soil moisture content. Soil texture will have been determined at the Tier 1 stage. The remaining parameters can be measured and used for Tier 2 adjustments. Sufficient measurements of each parameter must be obtained to establish a representative value for each soil unit or stratum that is relevant to the governing exposure pathway. Sampling must describe spatial and temporal variability associated with the parameter and demonstrate that estimate of risk is conservative based on the sampling variability.

Moisture content may vary seasonally and may also be different beneath buildings. It is necessary to obtain measurements that are representative of long-term, stable conditions and are appropriate to the soils of concern. The sampling methodology must be able to describe seasonal variations in moisture content.

Sampling methodology must target the appropriate depth and spatial locations relative to the model input parameters. For instance, permeability is used in the vapour inhalation model at or near the building foundation and therefore, permeability measurements must represent the condition at the default depths for both slab on grade and basement structures. Sampling protocols must be sufficient to completely describe potential for variability across the entire contaminated area and/or potential area of receptor concern, depending on the needs of the model.

Further details on sampling requirements are provided in Appendix C. As noted previously, an understanding of the exposure pathways and associated fate and transport processes is necessary to identify the dominant soil type for each exposure pathway.

Parameter determination will also need to account for the way it is applied within the model. For instance, soil vapour permeability is related to soil texture, porosity and moisture content and is therefore not commonly measured independently. Since it may vary significantly between closely-spaced locations, a stable, long-term value representative of a stratigraphic unit as a whole, should be determined.

7.1.2 Hydrogeological Conditions

Hydrogeological conditions include depth to groundwater table, hydraulic conductivity, and hydraulic gradient; these parameters are obtained from a site-specific groundwater investigation. The vertical separation between the lower limit of contaminated soil and the groundwater table is also relevant to the groundwater pathways.

Where the point of compliance is at some distance from the contaminated site, hydrogeological parameters must be representative of the conditions both on-site and along the groundwater transport pathway. For instance, where the aquatic receptor is being assessed, Tier 2 modifications must consider the relevant pathway between the aquatic receptor and the contaminant source.

7.1.3 Site Dimensions and Distances to Receptors

Contaminant source length and width are adjustable parameters with respect to the soil-to-groundwater pathway. Length and width dimensions are measured parallel and perpendicular to the principal groundwater flow direction, respectively. Site-specific distances from the edge of the contamination to receptor locations may also be parameters that can be adjusted at Tier 2. Three types of receptor distance measurements do not lead to land or water restrictions and are allowed at Tier 2, namely,

- Distance to fixed surface water bodies,
- Distance from a contaminant plume to a more sensitive land use. For instance, if the contaminant is on an industrial site with residential zoning nearby, the distance between the edge of the contaminant plume and

the residential zoning may be considered at Tier 2 Guideline Adjustment to determine if the residential land use offsite is protected or,

- Distance from a contaminant plume to a building that is more sensitive than assumed at Tier 1. For example, lateral offsets between the contaminant plume and the building may be employed at Tier 2 for a building with an earthen floor basement provided that generic default building parameters are used to calculate the objectives at all other points on the site.

7.1.4 Secondary User-Adjustable Parameters

A number of other parameters are influential but may not be well-suited to Tier 2 adjustment due to the fact that they are not readily measured, they cannot be controlled in a generic way or they lead to site-specific restrictions that would require use of Exposure Control. These include lateral distance to a building (inhalation receptor) and building characteristics (foundation configuration, presence of cracks, air exchange rate, etc.). These are indicated in Table 6 and identified as not being adjustable at Tier 2.

7.2 Tier 2 Guideline Adjustment based on Site-specific Parameters

For Tier 2 Guideline Adjustment, recalculation of the Tier 1 guideline values to determine site-specific Tier 2 values must be performed using the same modeling procedures (i.e. equations, algorithms, models) and default parameters and assumptions used in the derivation of the Tier 1 values, with the exception of the parameters for which a site-specific substitution is being made. This requirement applies to the determination of both soil and groundwater objectives.

In deciding to employ guideline adjustment, the proponent makes a commitment to reassess all appropriate parameters where the model is sensitive to changes even when changes to the default parameter may result in significantly more stringent guidelines. Therefore, it may be necessary to conduct a sensitivity analysis before proceeding to a field assessment to determine which parameters may be of importance.

Where typical field measurements will lead to less stringent guidelines, but where the value is difficult to verify in the field due to temporal variations, the measurement may not be necessary if it can be readily justified. For instance, due to the temporal variability in moisture content, it is difficult to accurately determine this measurement without the use of long-term monitoring in the field. However, it may be possible to substitute a default moisture content scenario if it is shown to be a conservative estimate.

Where it is not appropriate to use the reference models (e.g. if site-specific conditions invalidate the original model, or if the proponent selects a different model based on preference or site-specific technical considerations) a more detailed SSRA will be required, see Part A, Section 5.

7.2.1 Recalculation of Soil and Groundwater Objectives

Once site-specific parameters have been determined and the applicability of Tier 2 for the subject site and governing exposure pathway(s) has been verified, Tier 2 soil guidelines are calculated in accordance with the methods described in Appendix C.

Typical ranges of potential adjustment are provided in Table C-1, Appendix C, for the primary adjustable parameters based on conditions expected to occur in Alberta. Where it is possible to measure values outside the range presented here for many of the parameters of interest, care should be taken to ensure the parameter is sufficiently representative and conservative. Where the remediation guideline becomes less stringent with parameter measurements outside the range, it is possible to estimate the limit of the value from the model calculation using the limits of the range provided without proceeding to the SSRA option. For example, the minimum permeability range noted is 10^{-12} cm². Where field measurements verify that the permeability of the soil is consistently lower than this value, a guideline value using 10^{-12} cm² as an input into the model would be appropriate as a Tier 2 Guideline Adjustment value.

Groups of related parameters are identified in Table C-2, Appendix C, together with the corresponding pathway(s) to which they pertain. These must always be measured as a group when proceeding to Tier 2.

7.2.2 Determination of Governing Objectives

The governing Tier 2 objective is the lowest of the applicable exposure pathway objectives following model adjustment or pathway exclusion. Exposure pathways other than the governing pathway at Tier 1 may become critical, once the adjustment is made. This outcome may limit the amount by which the Tier 2 objective can vary from the Tier 1 guideline, unless the new governing value is also eligible for Tier 2 adjustment.

7.3 Tier 2 Decision and Management

The Tier 2 decision process is illustrated schematically by the lower part of the flow diagram presented in Figure 3. The process consists of a number of decision nodes. The decision process and criteria at each node are discussed in the following paragraphs.

7.3.1 Comparison of Conditions with Identified Tier 2 Objectives

Initially the measured contaminant concentrations are compared with the adjusted numerical objectives established using Tier 2 Guideline Adjustment. If no exceedances are found at this point, the site can be considered to be in compliance with Tier 2 and no further action is necessary. If exceedances are found, remediation to the Tier 2 objective or Exposure Control is required. In some instances, the proponent may reassess whether the site requires more detailed adjustments than allowed via the guideline adjustment pathway and proceed to a more detailed SSRA, as outlined in Figure 3.

7.3.2 Site-Specific Risk Assessment

Since the options for including site-specific information that may be input into the models at Tier 2 are limited, the guideline adjustment option does not capture all site-specific circumstances that may be important in accounting for exposure risk. Additional site-specific factors that may exist and are not accounted for in Tier 2 guideline adjustment may be accounted for using a more detailed Tier 2 SSRA to obtain site closure.

8. Assessment of Opportunity for Exposure Control

Exposure Control is also an option but will not lead to regulatory closure. Examples of site-specific exposure control options include:

- site-specific, manageable human receptor characteristics, such as frequency of exposure
- present building location and configuration
- restrictions on human access
- nature and location of existing water use and opportunity to manage future use
- use of engineered controls (e.g. physical or chemical barriers, hydraulic controls)

The *Alberta Exposure Control Guide* (AEP, 2016b) and the *Alberta Risk Management Plan Guide* (AEP, 2017b) provide the conditions under which Exposure Control can be considered and the requirements that the risk management plan must meet.

9. References

Alberta Environment and Parks references are available at:

<https://www.alberta.ca/ministry-environment-parks.aspx>

- AENV (Alberta Environment), 2009. Soil Remediation Guidelines for Barite: Environmental Health and Human Health. Environmental Assurance Division, Alberta Environment.
- AENV (Alberta Environment), 2010a. Soil and Groundwater Remediation Guidelines for Monoethanolamine and Diethanolamine. Environmental Assurance Division. Alberta Environment.
- AENV (Alberta Environment), 2010b. Soil and Groundwater Remediation Guidelines for Diethylene Glycol and Triethylene Glycol. Environmental Assurance Division. Alberta Environment.
- AEP (Alberta Environment and Parks), 2016a. Alberta Environmental Site Assessment Standard. Land Policy Branch, Policy and Planning Division.
- AEP (Alberta Environment and Parks), 2016b. Alberta Exposure Control Guide. Land Policy Branch, Policy and Planning Division.
- AEP (Alberta Environment and Parks), 2016c. Soil Remediation Guidelines for Boron – Environmental and Human Health. Land Policy Branch. Policy and Planning Division.
- AEP (Alberta Environment and Parks), 2017a. Guidance for Selecting Toxicity Reference Values for Alberta Tier 1 and Tier 2 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division.
- AEP (Alberta Environment and Parks), 2017b. Alberta Risk Management Plan Guide. Land Policy Branch, Policy and Planning Division.
- ATSDR (Agency for Toxic Substances and Disease Registry), 1995. Toxicological Profile for Polycyclic Aromatic Hydrocarbons. U.S. Department of Health and Human Services. Public Health Service. August 1995.
- ATSDR (Agency for Toxic Substances and Disease Registry), 2005. Toxicological Profile for Naphthalene, 1-Methylnaphthalene, and 2-Methylnaphthalene. U.S. Department of Health and Human Services. Public Health Service. August 2005.
- BCMELP (British Columbia Ministry of Environment, Lands, and Parks), 1996. Overview of CSST Procedures for the Derivation of Soil Quality Matrix Standards for Contaminated Sites.
- CCME (Canadian Council of Ministers of the Environment), 1999 and updates. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment, Winnipeg.
- CCME (Canadian Council of Ministers of the Environment), 2006a. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines. Canadian Council of Ministers of the Environment 2006.
- CCME (Canadian Council of Ministers of the Environment), 2006b. Canadian Soil Quality Guidelines for Diisopropanolamine (DIPA) (Environmental and Human Health Effects). Scientific Supporting Document.
- CCME (Canadian Council of Ministers of the Environment), 2006c. Canadian Soil Quality Guidelines for Sulfolane (Environmental and Human Health Effects). Scientific Supporting Document.
- CCME (Canadian Council of Ministers of the Environment), 2007. Canadian Soil Quality Guidelines for Trichloroethylene (Environmental and Human Health Effects). Scientific Supporting Document. 85pp
- CCME (Canadian Council of Ministers of the Environment), 2008a. Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale.

- CCME (Canadian Council of Ministers of the Environment), 2010. Canadian Soil Quality Guidelines Carcinogenic and Other Polycyclic Aromatic Hydrocarbons (PAHs) (Environmental and Human Health Effects). Scientific Supporting Document. PN 1445. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- CCME (Canadian Council of Ministers of the Environment), 2014. A Protocol for the Derivation of Soil Vapour Quality Guidelines for Protection of Human Exposures Via Inhalation of Vapours, PN 1531. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- CCME (Canadian Council of Ministers of the Environment), 2015a. A Protocol for the Derivation of Groundwater Quality Guidelines for Use at Contaminated Sites. PN 1533. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- CCME (Canadian Council of Ministers of the Environment), 2015b. Scientific Criteria Document for Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Nickel. PN 1540. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- CCME (Canadian Council of Ministers of the Environment), 2017. Scientific Criteria Document for the Development of the Canadian Soil Quality Guidelines for Methanol, Protection of Environmental and Human Health.. PN 1573. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- CCME (Canadian Council of Ministers of the Environment), 2020. Ecological Risk Assessment Guidance Document. PN 1585. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- CCME (Canadian Council of Ministers of the Environment), 2021. Scientific Criteria Document for the Development of the Canadian Soil and Groundwater Quality Guidelines for the Protection of Environmental and Human Health: Perfluorooctane Sulfonate (PFOS). PN 1625. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- EC (Environment Canada), 1999a. Canadian Soil Quality Guidelines for DDT. Environmental Effects. Scientific Supporting Document. National Guidelines and Standards Office, Environmental Quality Branch, Environment Canada, Ottawa. December 1999.
- EC (Environment Canada), 1999b. Canadian Soil Quality Guidelines for Ethylene Glycol. Environmental Effects. Scientific Supporting Document. National Guidelines and Standards Office, Environmental Quality Branch, Environment Canada, Ottawa. Based on 1997 Assessment. Revised December 1999.
- EC (Environment Canada), 2000. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life and Canadian Tissue Residue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota: Polychlorinated Dibenzo-P-Dioxins and polychlorinated Dibenzofurans (PCDD/Fs). Technical Supporting Document. 2 vols. Report # 1-2. National Guidelines and Standards Office, Environmental Quality Branch, Environment Canada, Ottawa.
- EC (Environment Canada), 2001. Canadian Soil Quality Guidelines for Polychlorinated Biphenyls (PCBs). Scientific Supporting Document. Report # 1-2. National Guidelines and Standards Office, Environmental Quality Branch, Environment Canada, Ottawa. August, 2001.
- EC (Environment Canada), 2002. Canadian Environmental Quality Guidelines for Nonylphenol and its Ethoxylates. Scientific Supporting Document, Water Sediment and Soil. Report # 1-3. National Guidelines and Standards Office, Environmental Quality Branch, Environment Canada, Ottawa. August, 2002.
- EC (Environment Canada), 2004a. Canadian Soil Quality Guidelines for Benzene. Technical Supporting Document. National Guidelines and Standards Office, Environmental Quality Branch, Environment Canada, Ottawa.
- EC (Environment Canada), 2004b. Canadian Soil Quality Guidelines for Toluene, Ethylbenzene and Xylenes (TEX). Technical Supporting Document. National Guidelines and Standards Office, Environmental Quality Branch, Environment Canada, Ottawa.
- ESRD (Alberta Environment and Sustainable Resource Development), 2007 and updates. Alberta Tier 1 Soil and Groundwater Remediation Guidelines, Land and Forestry Policy Branch, Policy Division.
- ESRD (Environment and Sustainable Resource Development), 2014a and updates. Environmental Quality Guidelines for Alberta Surface Waters. Water Policy Branch, Policy Division.

- ESRD (Environment and Sustainable Resource Development), 2014b. Contaminated Sites Policy Framework. Land and Forestry Policy Branch, Policy Division
- GOA (Government of Alberta). 2022a. Guide to Excluding the Domestic Use Aquifer (DUA) based on Municipal By-laws.
- GOA (Government of Alberta). 2022b. Supplemental Guidance on Site-Specific Risk Assessments in Alberta
- Gustafson, J.B., Tell, J.G., and Orem, D., 1997. Total Petroleum Hydrocarbon Criteria Working Group Series, Volume 3, Selection of Representative TPH Fractions Based on Fate and Transport Considerations. Amherst Scientific Publishers, Massachusetts.
- Health Canada, 2004a. Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Prepared by: Environmental Health Assessment Services Safe Environments Programme, September 2004.
- Health Canada, 2004b. Federal Contaminated Site Risk Assessment in Canada. Part II: Health Canada Toxicological Reference Values (TRVs). Prepared by: Environmental Health Assessment Services Safe Environments Programme, September 2004.
- HC (Health Canada). 1986a. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Chlorpyrifos. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1986b. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Diazinon. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1986c. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Malathion. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1986d. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Metolachlor. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1986e. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Paraquat. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1986f. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Phorate. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1986g. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Simazine. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1987a. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Chlorophenols. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1987b. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Diclofop-methyl. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1987c. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Diuron. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1987d. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Glyphosate. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1989a. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Azinophos-Methyl. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1989b. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Bromoxynil. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1989c. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Diquat. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1990. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Picloram. Health Canada. Ottawa, Ontario.

- HC (Health Canada). 1991a. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Carbaryl. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1991b. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Carbofuran. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1992a. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Trifluralin. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1993. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Atrazine. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada. Ottawa, Ontario H128-1/10-620E.
- HC (Health Canada). 1995a. Guidelines for Canadian Drinking Water Quality. Part I: Approach to the Derivation of Drinking Water Guidelines. Federal–Provincial–Territorial Committee on Drinking Water, February 1995.
- HC (Health Canada). 1995b. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Terbufos. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 1996. Canadian Environmental Protection Act, Priority Substances List, Supporting Documentation: Health-Based Tolerable Daily Intakes/Concentrations and Tumourigenic Doses/Concentrations for Priority Substances (unedited version). Health Canada. Environmental Health Centre. Ottawa, Ontario. August 1996.
- HC (Health Canada). 2004. Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Prepared by: Environmental Health Assessment Services Safe Environments Programme, September 2004.
- HC (Health Canada). 2006. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Trihalomethanes. Federal–Provincial–Territorial Committee on Drinking Water.
- HC (Health Canada). 2009a. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – 2,4-dichlorophenoxyacetic Acid. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 2009b. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Dimethoate. Health Canada. Ottawa, Ontario.
- Health Canada, 2010. Federal Contaminated Site Risk Assessment in Canada, Part VII: Guidance for Soil Vapour Intrusion Assessment at Contaminated Sites. H128-1/11-635E
- HC (Health Canada). 2010. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – 2-Methyl-4-chlorophenoxyacetic acid (MCPA). Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada. Ottawa, Ontario H128-1/10-620E.
- HC (Health Canada). 2014. Guidelines for Canadian Drinking Water Quality, Supporting Documents – Dicamba. Health Canada. Ottawa, Ontario.
- HC (Health Canada). 2017. Summary Document Indoor Air Reference Levels for Chronic Exposure to Volatile Organic Compounds. Health Canada, Ottawa, Ontario. October 2017.
- HC (Health Canada). 2021a. Federal Contaminated Site Risk Assessment in Canada, Toxicological Reference Values (TRVs) Version 3.0. March 2021.
- HC (Health Canada). 2021b. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Metribuzin. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada. Ottawa, Ontario. H144-13/19-2021E.
- HC (Health Canada). 2021c. Guidelines for Canadian Drinking Water - Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.
- Johnson, P.C. and R.A. Ettinger. 1991. Heuristic model for predicting the intrusion rate of contaminant vapors into buildings. *Environmental Science and Technology* 25: 1445-1452.
- Johnson, P.C. 2002. Identification of critical parameters for the Johnson and Ettinger (1991) vapour intrusion model. American Petroleum Institute. May 2002.

- MEMS (Millennium EMS Solutions Ltd.), 2016. Disinfection By-product Chloroform in Shallow Groundwater Within the City of Calgary. Prepared for the City of Calgary.
- NRC (National Research Council), 1996. Nutrient Requirements of Beef Cattle. National Academy Press, Washington, DC.
- ORNL (Oak Ridge National Laboratory), 2006. Risk Assessment Information System. On-Line Database, available at rais.ornl.gov (Accessed June 22, 2021)
- SRC (Syracuse Research Corporation), 2006. PhysProp Physical Properties Database, available online at <http://www.srcinc.com/what-we-do/efdb.aspx> (Accessed March 19, 2014)
- US EPA (United States Environmental Protection Agency), 1993. Wildlife Exposure Factors Handbook. Office of Research and Development. December 1993 EPA/600/R-93/187.
- US EPA (United States Environmental Protection Agency), 1996a. Soil Screening Guidance: Technical Background
- US EPA (United States Environmental Protection Agency), 1996b. Reregistration Eligibility Decision (RED) Bromacil. EPA 738-R-96-013. <http://www.epa.gov/oppsrrd1/REDS/0041red.pdf>
- United States Environmental Protection Agency (US EPA). 2003. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. Prepared by Environmental Quality Management, Inc. Office of Emergency and Remedial Response, Washington, DC.
- US EPA (United States Environmental Protection Agency), 2006. Integrated Risk Information System (IRIS) On-Line Database available at www.epa.gov/iris (June 22, 2021).

TABLE 1. EXAMPLES OF CONDITIONS UNDER WHICH TIER 1 DOES NOT APPLY

Condition	Response Required
Land/water use not captured by generic Tier 1 land uses	Site-specific risk assessment
Exposure pathway is present that is not considered at Tier 1 for the land use	Add exposure pathway (Tier 1 or Tier 2) or proceed to site-specific risk assessment
Human receptors spend more time at the site on average, or receive higher levels of exposure than assumed at Tier 1 for the land use (e.g. higher produce consumption from site)	Tier 2 Guideline Adjustment or site-specific risk assessment or apply more conservative land use at Tier 1
Ecological receptors with high sensitivity	Site-specific risk assessment to ensure sensitive species are protected level
Atypical building construction (earthen floors, crawlspace, low air exchange, etc.)	Generally Tier 2 Guideline Adjustment but may require more detailed site-specific risk assessment
Surface water body within 10 m of contamination	Tier 2 Guideline Adjustment or site-specific risk assessment
Contaminated groundwater in contact with stagnant surface water body	Site-specific risk assessment
Coarse sand/gravel soils with Darcy velocity greater than the default velocity (3×10^{-7}). This may occur for sites with high hydraulic conductivity (> 320 m/y) or where groundwater gradients are greater than those used in the default Tier 1 guidelines (0.028 m/m).	Tier 2 Guideline Adjustment or site-specific risk assessment
Contaminated soil source within 30 cm of existing building foundation or contaminated groundwater or capillary fringe that has potential to be within 30 cm of the building (based on potential for seasonal groundwater fluctuation).	Conduct Tier 2 Guideline Adjustment for the vapour inhalation pathway using a default attenuation coefficient of 0.01 (dilution factor of 100) or proceed to site-specific risk assessment.
Contamination in fractured bedrock	Site-specific risk assessment

Note: This list is not exhaustive; it is the responsibility of the proponent to identify any conditions that may violate the underlying assumptions of Tier 1 and ensure alternate remediation values meet human health and ecological protection objectives.

TABLE 2 EXPOSURE PATHWAYS AND RECEPTORS FOR EACH LAND USE^A

Pathway	Natural area	Agricultural	Residential/ Parkland	Commercial	Industrial
Direct Contact with Soil	Soil Nutrient and Energy Cycling Processes, Soil Invertebrates, Plants, Wildlife	Humans (all ages), Soil Nutrient and Energy Cycling Processes, Soil Invertebrates, Crops/Plants, Livestock, Wildlife	Humans (all ages), Soil Nutrient and Energy Cycling Processes, Soil Invertebrates, Plants, Wildlife	Humans (all ages), Soil Nutrient and Energy Cycling Processes, Soil Invertebrates, Plants, Wildlife	Humans (all ages), Soil Nutrient and Energy Cycling Processes, Soil Invertebrates, Plants, Wildlife
Direct Contact with Water	Aquatic Life, Plants and Soil Invertebrates	Aquatic Life, Plants and Soil Invertebrates	Aquatic Life, Plants and Soil Invertebrates	Aquatic Life, Plants and Soil Invertebrates	Aquatic Life, Plants and Soil Invertebrates
Indoor Vapour Inhalation	N/A	Humans (all ages)	Humans (all ages)	Humans (all ages)	Humans (adults)
Ingestion of Water	Humans (all ages) Wildlife	Humans (all ages), Livestock, Wildlife	Humans (all ages).	Humans (all ages)	Humans (all ages)
Soil and Food Ingestion	Wildlife	Humans (all ages), Wildlife, Livestock	Humans (all ages), Wildlife	See note b	See note b

^a Table 2 represents typical scenarios considered at Tier 1 and does not represent an exhaustive list of pathways and receptors. For more detail, see Table 5 and CCME (2006a).

^b Although the pathway is generally not applied, some consideration may be required for substances that biomagnify or bioaccumulate through the food chain. See CCME (2006a) for more details.

TABLE 3 HUMAN HEALTH EXPOSURE PATHWAYS FOR DEVELOPMENT OF SOIL QUALITY GUIDELINES^a

Pathway	Agriculture	Residential/ Parkland	Commercial	Industrial
Direct Contact with Soil	All	All	All	All
Ingestion of Potable Groundwater	Soluble	Soluble	Soluble	Soluble
Indoor Vapour Inhalation	Volatile (basement and slab-on-grade)	Volatile (basement and slab-on-grade)	Volatile (slab-on-grade)	Volatile (slab-on-grade)
Consumption of produce, meat, and milk	Required for bioaccumulating; recommended for all	Produce only	None	None
Offsite migration	None	None	All	All

^a Table 3 represents typical scenarios considered at Tier 1 and does not represent an exhaustive list of pathways and receptors. For more detail, see Table 5 and CCME (2006a).

All = pathway is evaluated for all chemicals

Soluble = pathway is evaluated for chemicals for which Alberta or Canadian water quality guidelines have been published, or which have solubility limits exceeding derived water quality objectives

Volatile = pathway is evaluated for chemicals for which the product of the water solubility and unitless Henry's law constant exceed published or derived tolerable concentration or risk-specific concentration

Bioaccumulating – pathway is evaluated for chemicals which may accumulate in biota

TABLE 4 ECOLOGICAL EXPOSURE PATHWAYS FOR DEVELOPMENT OF SOIL QUALITY GUIDELINES^a

Pathway	Natural	Agricultural	Residential/ Parkland	Commercial	Industrial
Soil Contact	All	All	All	All	All
Soil Ingestion: 1° consumers	All	All	Biomagnifying	None	None
Soil Ingestion: 2° and 3° consumers	Biomagnifying	Biomagnifying	Biomagnifying	None	None
Nutrient and Energy Cycling	All	All	All	All	All
Groundwater: Freshwater Life	Soluble	Soluble	Soluble	Soluble	Soluble
Groundwater: Agricultural (Irrigation & Livestock Watering)	Soluble	Soluble	None	None	None
Offsite migration	None	None	None	All	All

^a Table 4 represents typical scenarios considered at Tier 1 and does not represent an exhaustive list of pathways and receptors. For more detail, see Table 5 and CCME (2006a).

1°, 2° and 3° consumers = The type of consumer refers to trophic levels on the food chain. Primary (1°) consumers may be considered either animals that feed on the plants (e.g. herbivores) or organisms that feed on organic material in the soil (e.g. earthworms). More detail is available in CCME 2006(a).

All = pathway is evaluated for all chemicals

Soluble = pathway is evaluated for chemicals for which Alberta or Canadian water quality guidelines have been published, or which have solubility limits exceeding derived water quality objectives

Volatile = pathway is evaluated for chemicals for which the product of the water solubility and unitless Henry's law constant exceed published or derived tolerable concentration or risk-specific concentration

Biomagnifying – pathway is evaluated for chemicals, which may increase in concentration as they move through a food chain

TABLE 5 EXCLUSION, RE-EVALUATION AND MODIFICATION OF PATHWAYS AT TIER 2

	PATHWAY	OPTIONS
Human Pathways	Direct Contact	Cannot be excluded or modified at Tier 2
	Vapour Inhalation	Can be modified but not excluded at Tier 2
	Protection of Potable Water	Can be modified (soil only) or excluded at Tier 2. For exclusion, DUA must be shown to be isolated from any contamination by a natural geologic barrier.
	Ingestion of Produce, Meat and Milk	Cannot be modified via Tier 2 Guideline Adjustment. Where detailed site-specific risk assessment is required, this pathway must be evaluated for all contaminants that have potential to biomagnify. Must be evaluated if there is potential for local produce, meat and/or milk to form a significant portion of the diet.
	Acute Exposure (pica events ^a)	Used as a check in guidelines development. Where detailed site-specific risk assessment is required, the endpoints must be screened against this scenario to ensure protection for all potential acute exposure events.
	Inhalation of Particulates	Particulate exposure has been assessed within Tier 1 guidance. For detailed site-specific risk assessments where this has potential to become a controlling pathway, this factor must be considered and monitoring must be comprehensive enough to include screening of this pathway.
Ecological Pathways	Direct Contact	Cannot be excluded or modified via Tier 2 Guideline Adjustment; may be eligible for Tier 2 site-specific risk assessment for certain chemicals.
	Soil and Food Ingestion (livestock/wildlife)	Cannot be excluded or modified via Tier 2 Guideline Adjustment. For detailed site-specific risk assessment, endpoints must be screened to ensure protection of: primary consumers at the site-specific level where populations may be more sensitive than in the default case, and secondary and tertiary consumers where contaminants may biomagnify.
	Protection of Aquatic Life	Can be modified at Tier 2. Can be excluded at Tier 2 if there is no surface water body within 300m down gradient or 100m up gradient. Exceptions exist for conservative substances.
	Livestock Watering	Can be modified (soil only) at Tier 2; can only be excluded at Tier 2 if there is no suitable aquifer or the aquifer can be shown to be isolated from any contamination
	Irrigation Water	Can be modified (soil only) at Tier 2; can only be excluded at Tier 2 if there is no suitable aquifer or the aquifer can be shown to be isolated from any contamination

	PATHWAY	OPTIONS
	Wildlife Watering	Can be modified at Tier 2. Can be excluded at Tier 2 if there is no surface water body within 300m down gradient or 100m up gradient. Exceptions exist for conservative substances.
	Nutrient and Energy Cycling	Used as a check for natural, agricultural and residential sites. Where detailed site-specific risk assessment is required, endpoints must be screened to ensure protection for nutrient and energy cycling.
Other Considerations	Offsite migration	Potentially applies to both human and ecological pathways. Cannot be modified or changed at Tier 2, but may be excluded if there is no potential for more sensitive land uses in the vicinity of the site. Where detailed site-specific risk assessment is required, must be screened for all commercial and industrial properties.
	Receptor sensitivity	Potentially applies to human and ecological exposure pathways. Where receptor sensitivity is greater than assumed in the Tier 1 generic land use description, Tier 2 is required to ensure that guidelines are protective for sensitive receptors.
	Risks other than direct toxicity.	May include factors such as aesthetics, explosive risk, worker exposure risks, potential for free phase formation damage to infrastructure, land management considerations etc. For detailed site-specific risk assessments, endpoints must be screened to ensure that they do not pose other risks to human health and the environment.
	Contaminant discharge into a stagnant water body.	In addition to other considerations, assessment of potential for long-term accumulation in the water body through the entire time of contaminant release must be considered.

^a The deliberate ingestion of soil by young children is often referred to as a pica event. In this instance, the term is used more broadly to define any event that would result in a high level acute exposure to a contaminant that may be toxic. It is generally assumed that a high acute exposure scenario will be most applicable to young children. This type of exposure is generally used as a check in the guidelines development. For SSRA, this check must be done to ensure the approach remains protective of acute exposure events.

TABLE 6 RESTRICTIONS ASSOCIATED TIER 2 MODEL PARAMETERS^A

Parameter	Land/Water Use Restrictions	Management Requirements	Tier at Which Parameter Can be Adjusted
Soil dry bulk density	No	None	Tier 2
Soil moisture content	No	None	Tier 2
Soil vapour permeability	No	None	Tier 2
Organic carbon fraction	No	None	Tier 2
Depth to contamination	No, with exceptions ^b	Assurance required that contamination will remain at specified depth if direct exposure pathway are excluded ^b	Tier 2 (adjustments to vapour inhalation and groundwater transport) Exposure Control (direct exposure pathway exclusion)
Depth to groundwater	No	None	Tier 2
Thickness of contamination	No	None	Tier 2
Hydraulic conductivity	No	None	Tier 2
Hydraulic gradient	No	None	Tier 2
Infiltration (recharge) rate	No	None	Cannot be adjusted at this time, with one exception ^c
Distance to potable water user	Yes	No potable water use within specified distance ^d	Only applies to Exposure Control due to requirement for water use restriction.
Distance to livestock watering	Yes	No livestock watering within specified distance ^d	Only applies to Exposure Control due to requirement for water use restriction.
Distance to irrigation water	Yes	No irrigation water use within specified distance ^d	Only applies to Exposure Control due to requirement for water use restriction.
Distance to surface water	No	None	Tier 2
Dimensions of contamination	No	None	Tier 2

Parameter	Land/Water Use Restrictions	Management Requirements	Tier at Which Parameter Can be Adjusted
Distance to building	Yes	No construction within management zone	Only applies to Exposure Control due to requirement for construction ^e
Building parameters	Yes	No changes to building configuration or mechanical systems	Only applies to Exposure Control due to requirement for construction ^f
Human receptor characteristics	Yes	Cannot be adjusted.	Only applies to Exposure Control.
Human exposure factors	Yes	Administrative controls (land use or access restrictions)	Only applies to Exposure Control due to requirement for construction. Where receptors may experience more exposure than the default Tier 1 case, adjustment is made at Tier 2.
Chemical properties and toxicity reference values	No	None	Cannot be adjusted ^g

^a Requirements for the measurement of model parameters are outlined in Appendix C.

^b Depth to contamination can be used to adjust but not exclude the vapour transport and groundwater models. Use of this parameter in sites that may be re-graded or use of depth to contamination to exclude direct exposure pathways generally leads to management restrictions. For Petroleum Hydrocarbons where management requirements are built into the Tier 1 guidance, this assurance can be assumed if soil management guidelines are directly adopted and contaminants are below 3 m depth.

^c The exception is that the fine soil recharge rate can be applied if there is a sufficient continuous layer of fine soil overlying a coarse aquifer (see Appendix C).

^d Point of compliance for closure is the entire Domestic Use Aquifer which may be used for the specified water use.

^e An exception is made for earthen floor buildings. In this case, distance to building may be applied to the existing building without use of Exposure Control provided the dimensions of the contaminant zone are stable or decreasing and the remainder of the site is assessed against the generic building parameters.

^f Modeling for an existing building more sensitive than the default for the land use (e.g. building with earthen floor) may be undertaken at Tier 2, provided modeling is also undertaken for the default building and the more conservative of the results applied.

^g Some specific exceptions exist but only where the chemical is present in a different form from that which is assumed in the default scenario (e.g. different valence state or part of a stable molecule). Where the chemical is stable in a form for which guidance already exists (e.g. use of barite vs barium), the stable form can be adopted. Where the form in question is more toxic than the default form, the site must be screened for protection against the more sensitive form (e.g. CrVI vs CrIII).

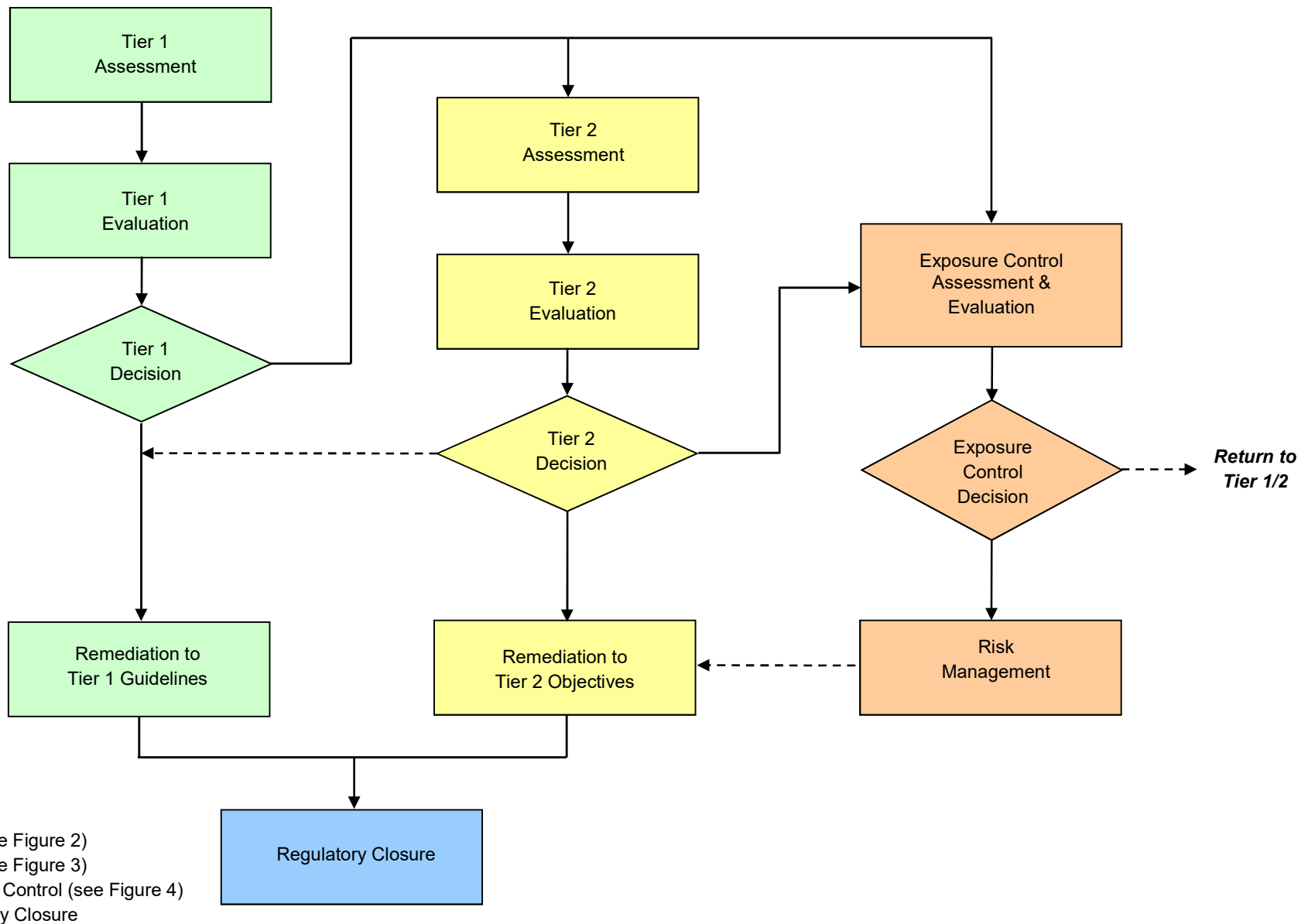


FIGURE 1: IMPLEMENTATION FRAMEWORK FOR TIER 1, TIER 2 AND EXPOSURE CONTROL GUIDELINES

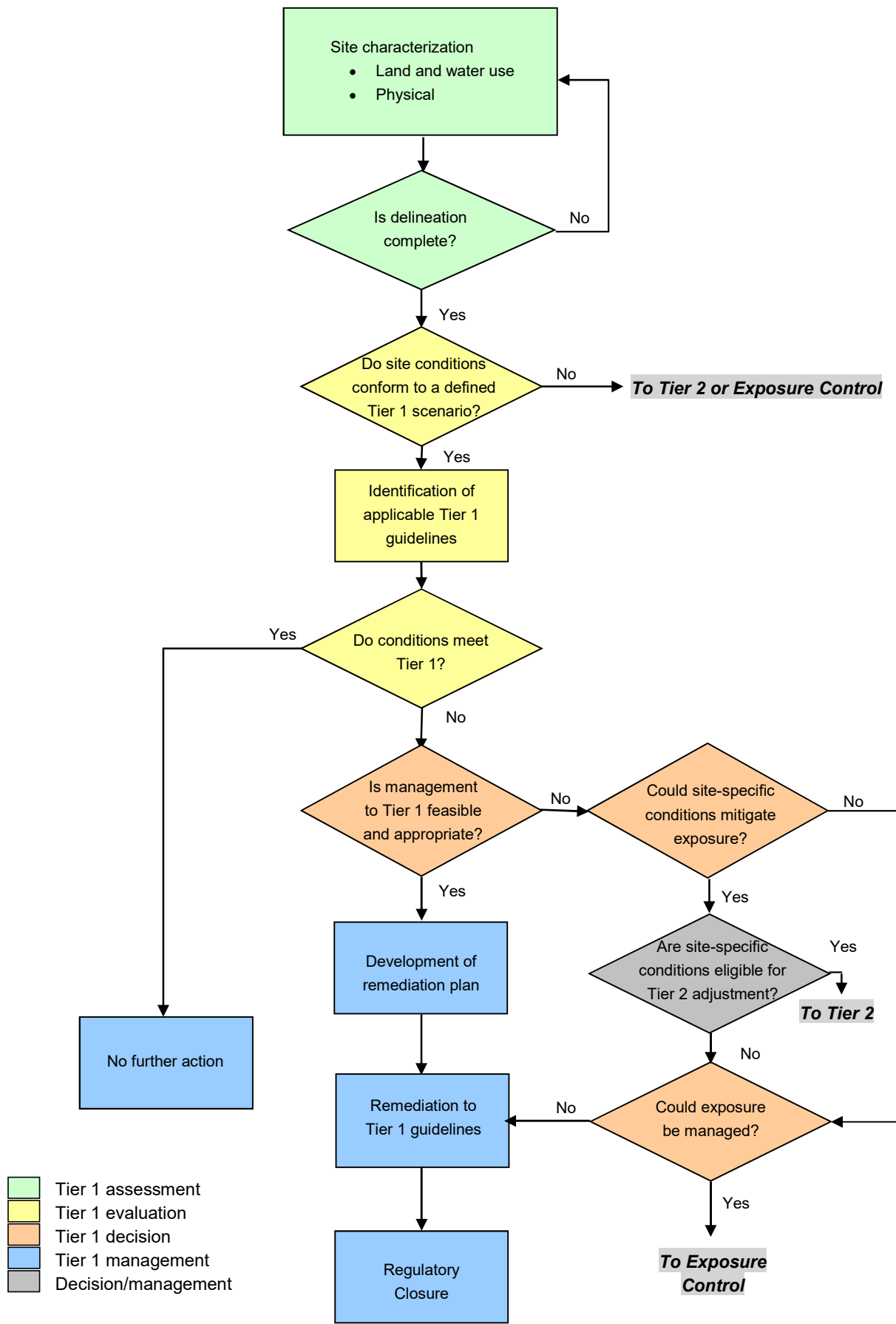


FIGURE 2: EXPANDED FLOW DIAGRAM – TIER 1

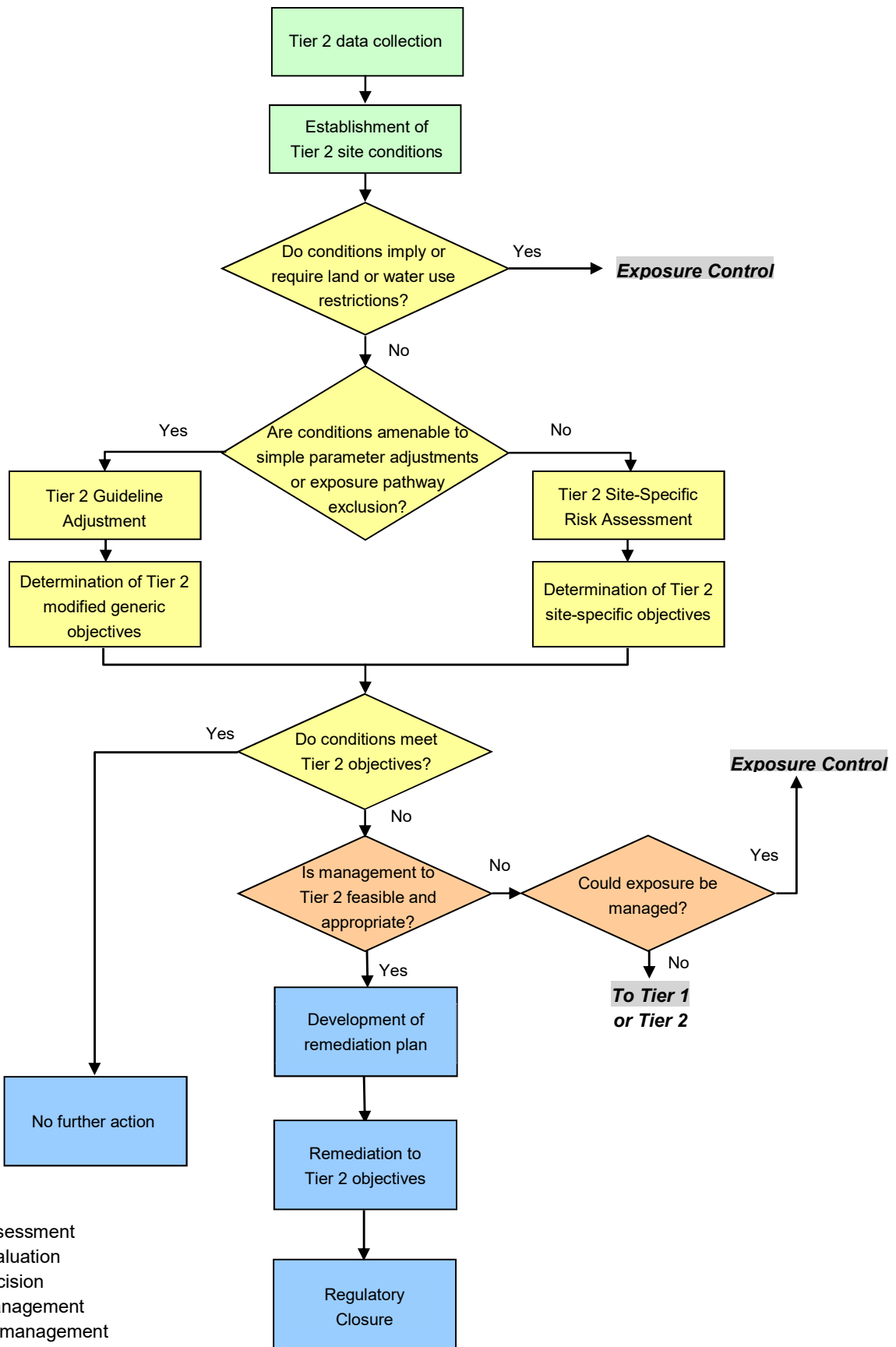
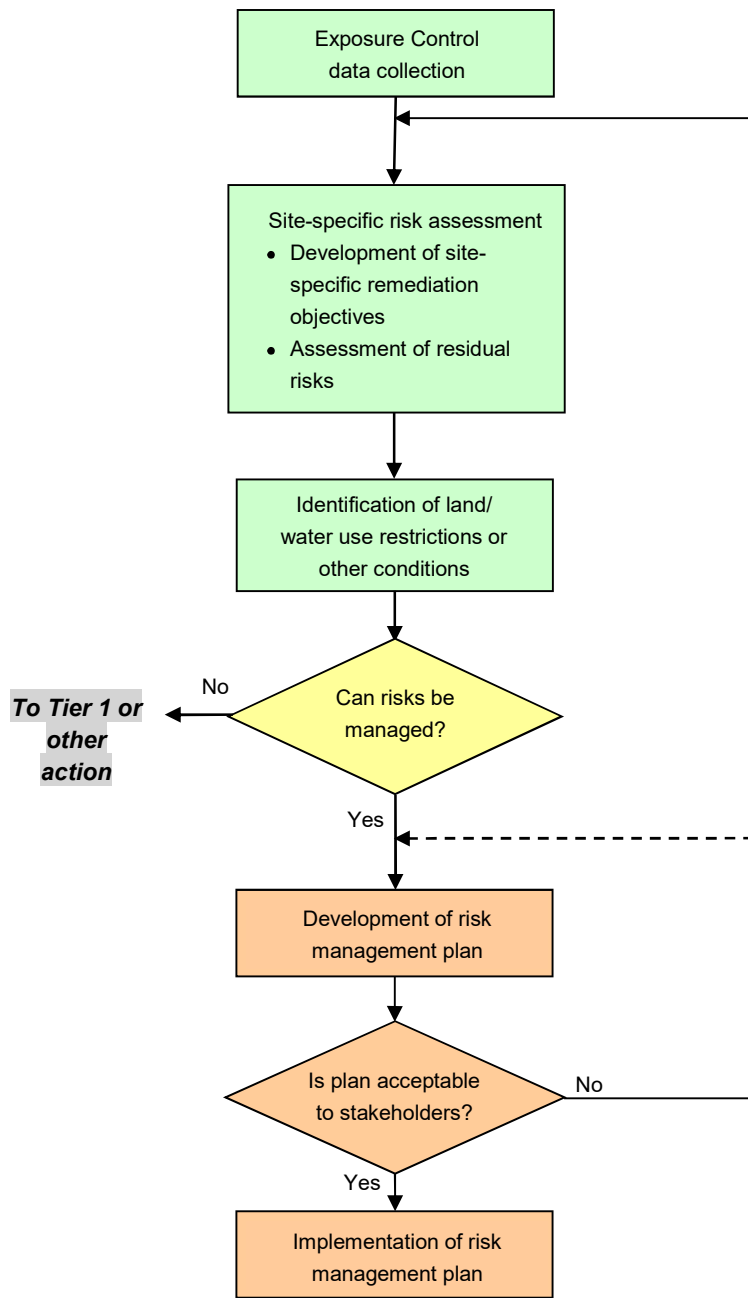


FIGURE 3: EXPANDED FLOW DIAGRAM – TIER 2



- Legend**
- Exposure Control assessment/evaluation
 - Exposure Control decision
 - Exposure Control risk management
 - Decision/management outside Exposure Control option

FIGURE 4: EXPANDED FLOW DIAGRAM – EXPOSURE CONTROL

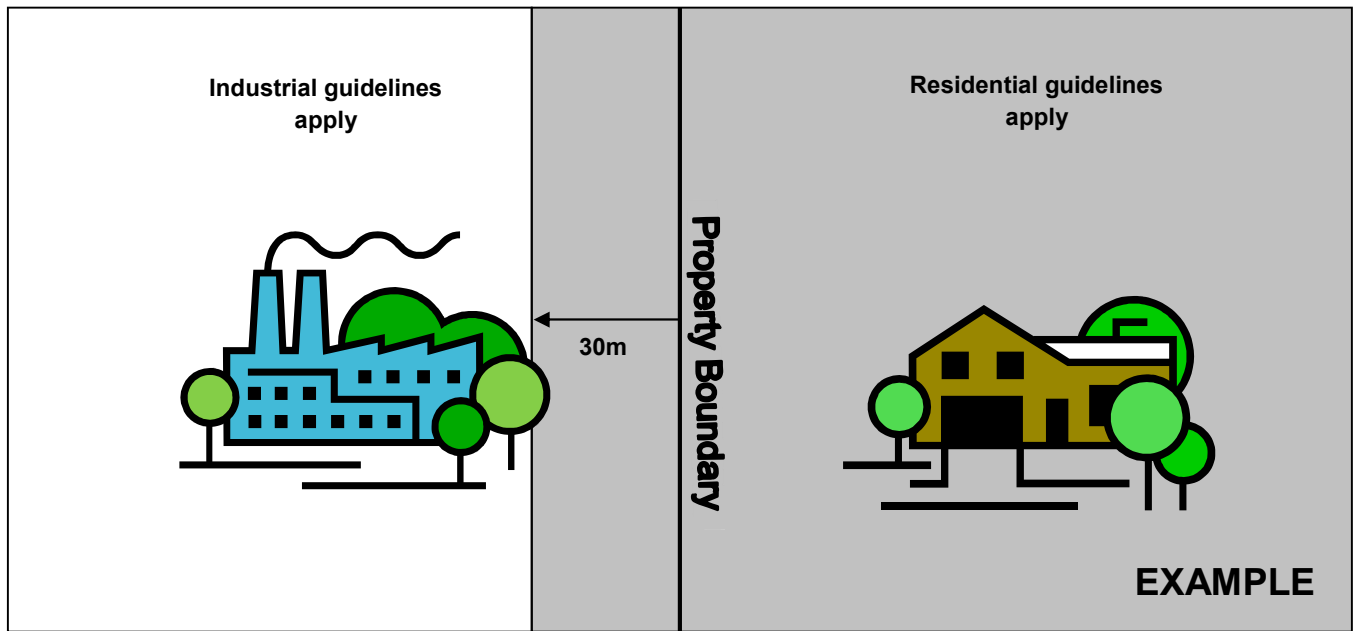


FIGURE 5: EXAMPLE OF THE 30 M BUFFER ZONE FOR THE MORE SENSITIVE LAND USE. THE DIAGRAM IS FOR ILLUSTRATION PURPOSES AND CAN BE APPLIED FOR ANY LAND USE SCENARIO WHERE A MORE SENSITIVE LAND USE IS ADJACENT TO A LESS SENSITIVE LAND USE.

Appendix A Default Parameters Used in the Derivation of Tier 1 Guidelines

List of Tables

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Table A-2	Soil and Hydrogeological Parameters
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Table A-5	Livestock and Wildlife Receptor Characteristics
Table A-6	Chemical Parameters
Table A-7	Human Toxicity Reference Values
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Table A-9	Human Background Exposure Parameters
Table A-10	Petroleum Hydrocarbon Subfraction Distribution
Table A-11	Surface Water Quality Guidelines

TABLE A-1. HUMAN RECEPTOR CHARACTERISTICS

Parameter	Symbol	Unit	Toddler	Adult
Body Weight	BW	kg	16.5	70.7
Air Inhalation Rate	IR	m ³ /d	9.3	15.8
Soil Inhalation Rate	IR _s	kg/d	7.1 x 10 ⁻⁹	1.2 x 10 ⁻⁸
Water Ingestion Rate	WIR	L/d	0.6	1.5
Soil Ingestion Rate	SIR	kg/d	0.00008	0.00002
Skin Surface Area				
- Hands	SA _H	m ²	0.043	0.089
- Other	SA _o	m ²	0.258	0.25
Dermal Loading to Skin				
- Hands	DL _H	kg/m ² -event	0.001	0.001
- Other	DL _o	kg/m ² -event	0.0001	0.0001
Dermal Exposure Frequency	EF	events/d	1	1
Exposure Term				
Exposure Term, agricultural and residential/parkland	ET	-	1	1
Exposure Term, commercial and industrial	ET	-	0.2747	0.2747
Exposure Term, agricultural and residential/parkland	ET ₁	-	1	1
Exposure Term, commercial and industrial	ET ₁	-	0.6593	0.6593
Exposure Term, agricultural and residential/parkland	ET ₂	-	1	1
Exposure Term, commercial and industrial	ET ₂	-	0.4167	0.4167

Notes:

All values from CCME (2006a)

TABLE A-2. SOIL AND HYDROGEOLOGICAL PARAMETERS

Parameter	Symbol	Unit	Fine Soil	Coarse Soil	Notes
Soil Bulk Density	ρ_b	g/cm^3	1.4	1.7	
Soil Total Porosity	θ_t	cm^3/cm^3	0.47	0.36	
Soil Moisture-Filled Porosity	θ_w	cm^3/cm^3	0.168	0.119	
Soil Vapour-Filled Porosity	θ_a	cm^3/cm^3	0.302	0.241	
Fraction of Organic Carbon	f_{oc}	$mass/mass$	0.005	0.005	
Saturated Hydraulic Conductivity	K	m/y	32	320	
Hydraulic Gradient	i	m/m	0.028	0.028	
Recharge (Infiltration) Rate	I	m/y	0.012	0.06	1
Soil Permeability to Vapour Flow	k_v	cm^2	10^{-9}	6×10^{-8}	2

Notes:

All parameters values from CCME (2006a) except as noted

1. See Section 2
2. Fine grained value from CCME (2008a)

TABLE A-3. SITE CHARACTERISTICS

Parameter	Symbol	Unit	Value
Contaminant Source Width Perpendicular to Groundwater Flow	Y	m	10
Contaminant Source Length Parallel to Groundwater Flow	X	m	10
Contaminant Source Depth	Z	m	3
Distance to Surface Water	x	m	10
Distance to Potable Water User	x	m	0
Distance to Agricultural Water User	x	m	0
Distance from Contamination to Building Slab	L _T	cm	30
Depth to Groundwater (water table)	d	m	3
Depth of Unconfined Aquifer	d _a	m	5
Transport time	t	yr	500

Notes:

All values from CCME (2006a)

Parameter	Symbol	Unit	Residential Basement		Residential Slab-on-Grade		Commercial Slab-on-Grade		Notes
			Other Hydrocarbons	Petroleum Hydrocarbons	Other Hydrocarbons	Petroleum Hydrocarbons	Other Hydrocarbons	Petroleum Hydrocarbons	
Adjustment Factor			1	10	1	10	1	10	1,2
Building Length	L_B	cm	1,225	1,225	1,225	1,225	2,000	2,000	
Building Width	W_B	cm	1,225	1,225	1,225	1,225	1,500	1,500	
Building Height (including basement)	H_B	cm	360	360	360	360	300	300	2
Area of Substructure	A_B	cm ²	2.7x10 ⁶	2.7x10 ⁶	1.5x10 ⁶	1.5x10 ⁶	3.0x10 ⁶	3.0x10 ⁶	
Thickness of Floor Slab	L_{crack}	cm	11.25	11.25	11.25	11.25	11.25	11.25	
Depth of Floor Slab Below Ground	Z_{crack}	cm	244	244	11.25	11.25	11.25	11.25	
Distance from Source to Slab:	L_T	cm							
surface soil			30	30	30	30	30	30	
subsoil			30	30	139	139	139	139	
Crack Area	A_{crack}	cm ²	994.5	994.5	994.5	994.5	1,846	1,846	
Crack Length	X_{crack}	cm	4,900	4,900	4,900	4,900	7,000	7,000	
Air Exchange Rate	ACH	exch/hr	0.5	0.5	0.5	0.5	0.9	0.9	2
Pressure Differential	ΔP	g/cm ² -s	40	40	40	40	20	20	

Notes:

All parameters values from CCME (2006a) except as noted.

1. An application factor of 10 is applied to the calculation for hydrocarbons only to account for empirical evidence of reduction in predicted indoor air concentrations. No data are available to support such a correction for non-hydrocarbons, and accordingly no application factor is used for non-hydrocarbons.

2. From CCME (2008a)

TABLE A-5. LIVESTOCK AND WILDLIFE RECEPTOR CHARACTERISTICS

Parameter	Symbol	Unit	Livestock (Cow) ^a	Wildlife (Meadow Vole)
Body Weight	BW	kg	550 ^a	0.017 ^c
Soil Ingestion Rate	SIR	kg/d	0.747 ^b	0.000058 ^d
Water Ingestion Rate	WIR	L/d	100 ^a	0.00357 ^a

Notes:

a. CCME (2006a)

b. NRC (1996)

c. US EPA (1993)

d. calculated; see text

TABLE A-6. CHEMICAL PARAMETERS

	Koc	Source	H'	Source	Da	Source	Solubility	Source	Half Life	Source
	ml/g		dimensionless		cm ² /s		mg/L		yr	
Metals										
Boron						See AEP (2016c)				
Hydrocarbons										
Benzene	81	EC (2004a)	0.225	EC (2004a)	8.80E-02	EC (2004a)	1780	Gustafson et al (1997)	1	BCMELP (1996)
Toluene	234	EC (2004b)	0.274	EC (2004b)	8.70E-02	EC (2004b)	515	Gustafson et al (1997)	0.288	BCMELP (1996)
Ethylbenzene	537	EC (2004b)	0.358	EC (2004b)	7.50E-02	EC (2004b)	152	Gustafson et al (1997)	0.312	BCMELP (1996)
Xylenes	586	EC (2004b)	0.252	EC (2004b)	7.80E-02	EC (2004b)	198	Gustafson et al (1997)	0.501	BCMELP (1996)
Styrene	461	Gustafson et al (1997)	0.123	Gustafson et al (1997)	7.10E-02	Gustafson et al (1997)	300	Gustafson et al (1997)		
F1									1.95	CCME (2008a)
F2									4.79	CCME (2008a)
Aliphatic C ₆ -C ₈	3,981	CCME (2008a)	50	CCME (2008a)	5.00E-02	CCME (2008a)	5.4	CCME (2008a)		
Aliphatic C ₈ -C ₁₀	31,623	CCME (2008a)	80	CCME (2008a)	5.00E-02	CCME (2008a)	0.43	CCME (2008a)		
Aliphatic C ₁₀ -C ₁₂	251,189	CCME (2008a)	120	CCME (2008a)	5.00E-02	CCME (2008a)	0.034	CCME (2008a)		
Aliphatic C ₁₂ -C ₁₆	5.01E+06	CCME (2008a)	520	CCME (2008a)	5.00E-02	CCME (2008a)	0.00076	CCME (2008a)		
Aliphatic C ₁₆ -C ₂₁	6.31E+08	CCME (2008a)	4900	CCME (2008a)	5.00E-02	CCME (2008a)	0.0000025	CCME (2008a)		
Aliphatic C ₂₁ -C ₃₄	1.0E+13	CCME (2008a)	5.6E+05	CCME (2008a)	5.00E-02	CCME (2008a)				
Aliphatic C _{>34}	1.6E+08	CCME (2008a)	1.2E+08	CCME (2008a)	5.00E-02	CCME (2008a)				
Aromatic C ₈ -C ₁₀	1,585	CCME (2008a)	0.48	CCME (2008a)	5.00E-02	CCME (2008a)	65	CCME (2008a)		
Aromatic C ₁₀ -C ₁₂	2,512	CCME (2008a)	0.14	CCME (2008a)	5.00E-02	CCME (2008a)	25	CCME (2008a)		
Aromatic C ₁₂ -C ₁₆	5,012	CCME (2008a)	0.053	CCME (2008a)	5.00E-02	CCME (2008a)	5.8	CCME (2008a)		
Aromatic C ₁₆ -C ₂₁	15,849	CCME (2008a)	0.013	CCME (2008a)	5.00E-02	CCME (2008a)	0.65	CCME (2008a)		
Aromatic C ₂₁ -C ₃₄	125,893	CCME (2008a)	0.00067	CCME (2008a)	5.00E-02	CCME (2008a)	0.0066	CCME (2008a)		
Aromatic C _{>34}	1.8E+06	CCME (2008a)	0.000018	CCME (2008a)	5.00E-02	CCME (2008a)				

TABLE A-6. CHEMICAL PARAMETERS

	Koc	Source	H'	Source	Da	Source	Solubility	Source	Half Life	Source
	ml/g		dimensionless		cm ² /s		mg/L		yr	
Acenaphthene	2,818	CCME (2010)	6.56E-03	CCME (2010)	4.21E-02	USEPA (1996a)	3.9	CCME (2010)		
Anthracene	19,953	CCME (2010)	0.0015	CCME (2010)	3.24E-02	USEPA (1996a)	0.057	CCME (2010)		
Fluoranthene	41,687	CCME (2010)	0.000609	CCME (2010)	3.03E-02	USEPA (1996a)	0.26	CCME (2010)		
Fluorene	4,898	CCME (2010)	0.00337	CCME (2010)	3.63E-02	USEPA (1996a)	1.9	CCME (2010)		
Naphthalene	708	CCME (2010)	0.020441	CCME (2010)	5.90E-02	USEPA (1996a)	31.7	CCME (2010)		
Phenanthrene	6,607	CCME (2010)	0.000986	CCME (2010)	2.72E-02	USEPA (1996a)	1.15	CCME (2010)		
Pyrene	69,183	CCME (2010)	0.000466	CCME (2010)	2.72E-02	USEPA (1996a)	1.35	CCME (2010)		
Benz[a]anthracene	199,526	CCME (2010)	0.000142	CCME (2010)	5.01E-02	USEPA (1996a)	0.0094	CCME (2010)		
Benzo[b+j]fluoranthene	93,325	CCME (2010)	0.000468	CCME (2010)	2.26E-02	USEPA (1996a)	0.00375	CCME (2010)		
Benzo[k]fluoranthene	19,953	CCME (2010)	0.0000351	CCME (2010)	2.26E-02	USEPA (1996a)	0.0008	CCME (2010)		
Benzo[g,h,i]perylene	407,380	CCME (2010)	0.00000597	CCME (2010)	4.48E-02	ORNL (2006)	0.000026	CCME (2010)		
Benzo[a]pyrene	2,187,762	CCME (2010)	0.0000478	CCME (2010)	4.30E-02	USEPA (1996a)	0.0016	CCME (2010)		
Chrysene	125,892	CCME (2010)	0.004	CCME (2010)	2.48E-02	USEPA (1996a)	0.00415	CCME (2010)		
Dibenz[a,h]anthracene	1,380,384	CCME (2010)	0.00000622	CCME (2010)	2.02E-02	USEPA (1996a)	0.00249	CCME (2010)		
Indeno[1,2,3-c,d]pyrene	1,584,893	CCME (2010)	0.0000677	CCME (2010)	1.90E-02	USEPA (1996a)	0.000022	CCME (2010)		
Halogenated Aliphatics										
Vinyl chloride	18.6	USEPA (1996a)	1.11	USEPA (1996a)	1.06E-01	USEPA (1996a)	2760	USEPA (1996a)		
1,1-Dichloroethene	65	USEPA (1996a)	1.07	USEPA (1996a)	1.04E-01	USEPA (1996a)	2250	USEPA (1996a)		
Trichloroethene (Trichloroethylene, TCE)	94	USEPA (1996a)	0.422	USEPA (1996a)	7.90E-02	USEPA (1996a)	1100	USEPA (1996a)	2.19	CCME (2007)
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	265	USEPA (1996a)	0.754	USEPA (1996a)	7.20E-02	USEPA (1996a)	200	USEPA (1996a)		
1,2-Dichloroethane	38	USEPA (1996a)	0.0401	USEPA (1996a)	1.04E-01	USEPA (1996a)	8520	USEPA (1996a)		
Dichloromethane (Methylene chloride)	23.74	ORNL (2006)	0.133	ORNL (2006)	1.01E-01	ORNL (2006)	1300	ORNL (2006)		

TABLE A-6. CHEMICAL PARAMETERS

	Koc	Source	H'	Source	Da	Source	Solubility	Source	Half Life	Source
	ml/g		dimensionless		cm ² /s		mg/L		yr	
Trichloromethane (Chloroform)	53.0	USEPA (1996a)	0.15	USEPA (1996a)	1.04E-01	USEPA (1996a)	7920	USEPA (1996a)	0.178	MEMS (2016)
Tetrachloromethane (Carbon tetrachloride)	152	USEPA (1996a)	1.25	USEPA (1996a)	7.80E-02	USEPA (1996a)	793	USEPA (1996a)		
Dibromochloromethane	35	ORNL (2006)	0.032	ORNL (2006)	1.96E-02	ORNL (2006)	2700	ORNL (2006)		
Chlorinated Aromatics										
Chlorobenzene	224	USEPA (1996a)	0.152	USEPA (1996a)	7.30E-02	USEPA (1996a)	472	USEPA (1996a)		
1,2-Dichlorobenzene	379	USEPA (1996a)	0.0779	USEPA (1996a)	6.90E-02	USEPA (1996a)	156	USEPA (1996a)		
1,3-Dichlorobenzene	434	ORNL (2006)	0.108	ORNL (2006)		USEPA (1996a)	125	ORNL (2006)		
1,4-Dichlorobenzene	616	USEPA (1996a)	0.0996	USEPA (1996a)	6.90E-02	USEPA (1996a)	73.8	USEPA (1996a)		
1,2,3-Trichlorobenzene			No data, assumed to be equal to other trichlorobenzene isomers							
1,2,4-Trichlorobenzene	1,659	USEPA (1996a)	0.0582	USEPA (1996a)	3.00E-02	USEPA (1996a)	49	ORNL (2006)		
1,3,5-Trichlorobenzene			No data, assumed to be equal to other trichlorobenzene isomers							
1,2,3,4-Tetrachlorobenzene			No data, assumed to be equal to other tetrachlorobenzene isomers							
1,2,3,5-Tetrachlorobenzene			No data, assumed to be equal to other tetrachlorobenzene isomers							
1,2,4,5-Tetrachlorobenzene	1,186	ORNL (2006)	0.0409	ORNL (2006)	2.11E-02	ORNL (2006)	0.595	ORNL (2006)		
Pentachlorobenzene	32,148	USEPA (1996a)	0.0287	ORNL (2006)	5.70E-02	ORNL (2006)	0.831	ORNL (2006)		
Hexachlorobenzene	80,000	USEPA (1996a)	0.0541	USEPA (1996a)	5.42E-02	USEPA (1996a)	6.2	USEPA (1996a)		
Dichlorophenol	718	ORNL (2006)	0.0000895	ORNL (2006)	3.46E-02	ORNL (2006)	4500	ORNL (2006)		
Trichlorophenol	1,186	ORNL (2006)	0.0000662	ORNL (2006)	2.91E-02	ORNL (2006)	1200	ORNL (2006)		
Tetrachlorophenol	2,002	ORNL (2006)	0.000361	ORNL (2006)	2.17E-02	ORNL (2006)	23	ORNL (2006)		
Pentachlorophenol	2,500	ORNL (2006)	1.00E-06	ORNL (2006)	5.60E-02	ORNL (2006)	14	ORNL (2006)		
Dioxins & Furans ²										
PCBs ²										

TABLE A-6. CHEMICAL PARAMETERS

	Koc	Source	H'	Source	Da	Source	Solubility	Source	Half Life	Source
	ml/g		dimensionless		cm ² /s		mg/L		yr	
Pesticides										
Aldicarb	32	ORNL (2006)	5.39E-05	ORNL (2006)	3.05E-02	ORNL (2006)	6030	ORNL (2006)		
Aldrin	106,000	ORNL (2006)	0.0018	ORNL (2006)	1.32E-02	ORNL (2006)	0.017	ORNL (2006)		
Atrazine	230	ORNL (2006)	9.65E-08	ORNL (2006)			35	ORNL (2006)		
Azinphos-methyl (Guthion)	231	SRC (2006) ¹	9.96E-07	SRC (2006)			20.9	SRC (2006)		
Bromacil	66.6	ORNL (2006)	5.27E-09	ORNL (2006)			815	ORNL (2006)		
Bromoxynil	435	ORNL (2006)	5.40E-09	ORNL (2006)	2.01E-02	ORNL (2006)	130	ORNL (2006)		
Carbaryl	242	ORNL (2006)	1.78E-07	ORNL (2006)	2.78E-02	ORNL (2006)	110	ORNL (2006)		
Carbofuran	71	ORNL (2006)	1.26E-07	ORNL (2006)			320	ORNL (2006)		
Chlorothalonil	2,392	ORNL (2006)	8.18E-05	ORNL (2006)			0.6	ORNL (2006)		
Chlorpyrifos	6,829	ORNL (2006)	0.00012	ORNL (2006)			1.12	ORNL (2006)		
2,4-D	29	ORNL (2006)	1.45E-06	ORNL (2006)	2.31E-02	ORNL (2006)	677	ORNL (2006)		
DDT	794,328	EC (1999a)	3.40E-04	ORNL (2006)	1.37E-02	ORNL (2006)	0.0055	ORNL (2006)		
Diazinon	1,337	ORNL (2006)	4.62E-06	ORNL (2006)	2.06E-02	ORNL (2006)	40	ORNL (2006)		
Dicamba	29	ORNL (2006)	8.91E-08	ORNL (2006)			8310	ORNL (2006)		
Diclofop-methyl	17,092	SRC (2006) ¹	8.21E-05	SRC (2006)			0.8	SRC (2006)		
Dieldrin	10,600	ORNL (2006)	0.000409	ORNL (2006)	1.25E-02	ORNL (2006)	0.25	ORNL (2006)		
Dimethoate	25	ORNL (2006)	4.29E-09	ORNL (2006)			25000	ORNL (2006)		
Dinoseb	3,544	ORNL (2006)	1.86E-05	ORNL (2006)			52	ORNL (2006)		
Diquat	1,933	ORNL (2006)	5.81E-12	ORNL (2006)			708000	ORNL (2006)		
Diuron	136	ORNL (2006)	2.06E-08	ORNL (2006)			42	ORNL (2006)		
Endosulfan	22,000	ORNL (2006)	0.00266	ORNL (2006)	1.15E-02	ORNL (2006)	0.45	ORNL (2006)		
Endrin	10,811	USEPA (1996a)	0.000308	USEPA (1996a)	1.25E-02	USEPA (1996a)	0.25	USEPA (1996a)		

TABLE A-6. CHEMICAL PARAMETERS

	Koc	Source	H'	Source	Da	Source	Solubility	Source	Half Life	Source
	ml/g		dimensionless		cm ² /s		mg/L		yr	
Glyphosate	19	ORNL (2006)	1.67E-17	ORNL (2006)	4.37E-02	ORNL (2006)	12000	ORNL (2006)		
Heptachlor epoxide	9,528	USEPA (1996a)	0.0447	USEPA (1996a)	1.12E-02	USEPA (1996a)	0.18	USEPA (1996a)		
Lindane	1,352	USEPA (1996a)	0.000574	USEPA (1996a)	1.42E-02	USEPA (1996a)	6.8	USEPA (1996a)		
Linuron	350	ORNL (2006)	2.56E-07	ORNL (2006)			75	ORNL (2006)		
Malathion	31	ORNL (2006)	2.00E-07	ORNL (2006)			143	ORNL (2006)		
MCPA	29	ORNL (2006)	5.44E-08	ORNL (2006)			630	ORNL (2006)		
Methoxychlor	80,000	USEPA (1996a)	0.000648	USEPA (1996a)	1.56E-02	USEPA (1996a)	0.045	USEPA (1996a)		
Metolachlor	292	ORNL (2006)	3.68E-07	ORNL (2006)			530	ORNL (2006)		
Metribuzin	1,196	ORNL (2006)	4.78E-09	ORNL (2006)			1050	ORNL (2006)		
Paraquat (as dichloride)	1,405	ORNL (2006)	1.32E-11	ORNL (2006)			620000	ORNL (2006)		
Phorate	444	ORNL (2006)	0.000179	ORNL (2006)			50	ORNL (2006)		
Picloram	18	ORNL (2006)	2.18E-12	ORNL (2006)			430	ORNL (2006)		
Simazine	149	ORNL (2006)	3.85E-08	ORNL (2006)			6.2	ORNL (2006)		
Tebuthiuron	23	ORNL (2006)	4.91E-09	ORNL (2006)			2500	ORNL (2006)		
Terbufos	979	ORNL (2006)	0.000981	ORNL (2006)			5.07	ORNL (2006)		
Toxaphene	95,816	USEPA (1996a)	0.000246	USEPA (1996a)	1.16E-02	USEPA (1996a)	0.74	USEPA (1996a)		
Triallate	1,641	ORNL (2006)	0.000789	ORNL (2006)			4	ORNL (2006)		
Trifluralin	9,682	ORNL (2006)	0.00421	ORNL (2006)	1.49E-02	ORNL (2006)	0.184	ORNL (2006)		
Other Organics										
Aniline	45	ORNL (2006)	8.26E-05	ORNL (2006)	7.00E-02	ORNL (2006)	36000	ORNL (2006)		
Di- <i>n</i> -butyl phthalate	1,460	ORNL (2006)	0.000074	ORNL (2006)	4.38E-02	ORNL (2006)	11.2	ORNL (2006)		
Dichlorobenzidine	7,489	ORNL (2006)	2.09E-09	ORNL (2006)	1.94E-02	ORNL (2006)	3.1	ORNL (2006)		
Diethanolamine	***1.9	AENV (2010a)	2.2E-12	AENV (2010a)			miscible	AENV (2010a)	0.75	AENV (2010a)

TABLE A-6. CHEMICAL PARAMETERS

	K _{oc}	Source	H'	Source	D _a	Source	Solubility	Source	Half Life	Source
	ml/g		dimensionless		cm ² /s		mg/L		yr	
Diethylene glycol	0.018	AENV (2010b)	5.3E-9	AENV (2010b)			miscible		0.68	AENV (2010b)
Diisopropanolamine	*** 2.2	CCME (2006b)	7.00E-06	CCME (2006b)			870000	CCME (2006b)		
Ethylene glycol	0.0072	EC (1999b)	2.50E-06	EC (1999b)	0.108	ORNL (2006)	miscible	EC (1999b)		
Hexachlorobutadiene	994	ORNL (2006)	0.421	ORNL (2006)	5.61E-02	ORNL (2006)	3.2	ORNL (2006)		
Methanol	0.27	CCME (2017)	0.0002	CCME (2017)	0.15	CCME (2017)	miscible		0.67	CCME (2017)
Methylmethacrylate	10	ORNL (2006)	0.0138	ORNL (2006)	7.70E-02	ORNL (2006)	15000	ORNL (2006)		
Monoethanolamine	***2.21	AENV (2010a)	1.7E-6	AENV (2010a)			miscible	AENV (2010a)	0.75	AENV (2010a)
MTBE	12	USEPA (1994)	0.023	USEPA (1994)	1.02E-01	ORNL (2006)	51000	USEPA (1994)		
Nonylphenol	141,254	EC (2002)	0.005	EC (2002)			5.43	EC (2002)		
Perfluorooctane sulfonate (PFOS)	1,445	CCME (2021)	1.44E-7	CCME (2021)			550	CCME (2021)		
Phenol	12	CCME (1999)	1.60E-05	CCME (1999)	0.082	ORNL (2006)	87,000	CCME (1999)		
Sulfolane	1.2	CCME (2006c)	3.60E-08	CCME (2006c)			miscible	CCME (2006c)		
Triethylene glycol	0.0051	AENV (2010b)	5.3E-9	AENV (2010b)			miscible		0.48	AENV (2010b)

Notes:

K_{oc} = organic carbon water partition coefficient

H' = dimensionless Henry's Law Coefficient

D_{air} = diffusion coefficient in air

na = not applicable or not available

***Value presented is a mean K_d, rather than a K_{oc} since compound sorbs to clays in preference to organic carbon.

¹ Calculated using the equation $K_{oc} = 0.41 \times K_{ow}$

² PCBs, dioxins and furans are groups of chemicals with a wide range of chemical properties. Chemical properties are not provided for these groups.

CCME (1999) refers to the Canadian Environmental Quality Guidelines (CEQG) and updates, including the scientific supporting documents that are summarized in the CEQG.

TABLE A-7. HUMAN TOXICITY REFERENCE VALUES

	Threshold TRV				Non-Threshold TRV			
	Oral TDI	Source	Inhalation TC	Source	Oral SF	Source	Inhalation UR	Source
	mg/kg-d		mg/m3		(mg/kg-d)-1		(mg/m3)-1	
Metals								
Arsenic (inorganic)					1.8	HC (2021a)		
Barite-barium	0.2	AENV (2009)						
Boron	0.2	AEP (2016c)						
Nickel (see note 2)	0.011	CCME (2015)	0.00002	CCME (2015)			0.0000013	CCME (2015)
Hydrocarbons								
Benzene					0.083	HC (2021a)	0.016	HC (2021a)
Toluene	0.0097	HC (2021a)	2.3	HC (2021a)				
Ethylbenzene	0.022	HC (2021a)	2	HC (2021a)				
Xylenes	0.013	HC (2021a)	0.1	HC (2021a)				
Styrene	0.12	HC (1996)	0.85	HC (2017)				
Aliphatic C ₆ -C ₈	5.0	CCME (2008a)	18.4	CCME (2008a)				
Aliphatic C _{>8} -C ₁₀	0.1	CCME (2008a)	1.0	CCME (2008a)				
Aliphatic C _{>10} -C ₁₂	0.1	CCME (2008a)	1.0	CCME (2008a)				
Aliphatic C _{>12} -C ₁₆	0.1	CCME (2008a)	1.0	CCME (2008a)				
Aliphatic C _{>16} -C ₂₁	2.0	CCME (2008a)						
Aliphatic C _{>21} -C ₃₄	2.0	CCME (2008a)						
Aliphatic C _{>34}	20	CCME (2008a)						
Aromatic C _{>8} -C ₁₀	0.04	CCME (2008a)	0.2	CCME (2008a)				
Aromatic C _{>10} -C ₁₂	0.04	CCME (2008a)	0.2	CCME (2008a)				
Aromatic C _{>12} -C ₁₆	0.04	CCME (2008a)	0.2	CCME (2008a)				
Aromatic C _{>16} -C ₂₁	0.03	CCME (2008a)						

TABLE A-7. HUMAN TOXICITY REFERENCE VALUES

	Threshold TRV				Non-Threshold TRV			
	Oral TDI	Source	Inhalation TC	Source	Oral SF	Source	Inhalation UR	Source
	mg/kg-d		mg/m3		(mg/kg-d)-1		(mg/m3)-1	
Aromatic C _{>21} -C ₃₄	0.03	CCME (2008a)						
Aromatic C _{>34}	0.03	CCME (2008a)						
Naphthalene	0.02	HC (2021a)	0.01	HC (2021a)				
Acenaphthene	0.06	US EPA (2006)	0.27	see note 1				
Fluorene	0.04	US EPA (2006)	0.18	see note 1				
Fluoranthene	0.04	US EPA (2006)	0.18	see note 1				
Anthracene	0.3	US EPA (2006)	1.34	see note 1				
Pyrene	0.03	HC (2021a)	0.13	see note 1				
Benzo(a)pyrene	0.0000667	HC (2021a)			1.289	HC (2021a)		
Halogenated Aliphatics								
Vinyl chloride					0.48	HC (2021a)	0.0088	HC (2021a)
1,1-Dichloroethene	0.003	HC (2021a)	0.2	US EPA (2006)				
Trichloroethene (Trichloroethylene, TCE)	0.00146	HC (2021a)	0.002	HC (2021a)	0.000811	HC (2021a)	0.0041	HC (2021a)
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	0.0047	HC (2021a)	0.04	HC (2021a)				
1,2-Dichloroethane					0.0033	HC (2021a)	0.026	US EPA (2006)
Dichloromethane (Methylene chloride)	0.014	HC (2021a)	0.6	HC (2021a)	0.002	HC (2021a)	0.00001	HC (2021a)
Trichloromethane (Chloroform)	0.0062	HC (2006)	0.3	HC (2017)				
Tetrachloromethane (Carbon tetrachloride)	0.00071	HC (2021a)	0.00318	see note 1				
Dibromochloromethane	0.02	US EPA (2006)	0.08949	see note 1				
Chlorinated Aromatics								
Chlorobenzene	0.43	HC (2021a)	0.01	HC (2021a)				
1,2-Dichlorobenzene	0.43	HC (2021a)	1.92411	see note 1				
1,4-Dichlorobenzene	0.11	HC (2021a)	0.06	HC (2021a)				

TABLE A-7. HUMAN TOXICITY REFERENCE VALUES

	Threshold TRV			Non-Threshold TRV				
	Oral TDI	Source	Inhalation TC	Source	Oral SF	Source	Inhalation UR	Source
	mg/kg-d		mg/m3		(mg/kg-d)-1		(mg/m3)-1	
1,2,3-Trichlorobenzene	0.0015	HC (1996)	0.00671	see note 1				
1,2,4-Trichlorobenzene	0.0016	HC (1996)	0.007	HC (1996)				
1,3,5-Trichlorobenzene	0.0015	HC (1996)	0.0036	HC (1996)				
1,2,3,4-Tetrachlorobenzene	0.0034	HC (1996)	0.01521	see note 1				
1,2,3,5-Tetrachlorobenzene	0.00041	HC (1996)	0.00183	see note 1				
1,2,4,5-Tetrachlorobenzene	0.00021	HC (1996)	0.00094	see note 1				
Pentachlorobenzene	0.001	HC (1996)	0.00447	see note 1				
Hexachlorobenzene	0.0008	US EPA (2006)	0.00358	see note 1	1.6	US EPA (2006)	0.46	US EPA (2006)
2,4-Dichlorophenol	0.1	HC (1987a)	0.447468	see note 1				
2,4,6-Trichlorophenol					0.02	HC (1987a)	0.0045	see note 1
2,3,4,6-Tetrachlorophenol	0.01	HC (1987a)	0.04475	see note 1				
Pentachlorophenol	0.006	HC (1987a)	0.02685	see note 1				
Dioxins and Furans	2.3E-09	HC (2021a)						
PCBs	0.00001	HC (2021a)						
Pesticides								
Aldicarb	0.001	US EPA (2006)						
Aldrin	0.00003	US EPA (2006)			17	US EPA (2006)	4.9	US EPA (2006)
Atrazine and metabolites	0.0005	HC (1993)						
Azinphos-methyl (Guthion)	0.0025	HC (1989a)						
Bromacil	0.1	US EPA (1996b)						
Bromoxynil	0.0005	HC (1989b)						
Carbaryl	0.01	HC (1991a)						
Carbofuran	0.01	HC (1991b)						
Chlorothalonil	0.015	US EPA (2006)						

TABLE A-7. HUMAN TOXICITY REFERENCE VALUES

	Threshold TRV			Non-Threshold TRV				
	Oral TDI	Source	Inhalation TC	Source	Oral SF	Source	Inhalation UR	Source
	mg/kg-d		mg/m3		(mg/kg-d)-1		(mg/m3)-1	
Chlorpyrifos	0.01	HC (1986a)						
2,4-D	0.01	HC (2009a)						
DDT	0.0005	US EPA (2006)			0.34	US EPA (2006)	0.097	US EPA (2006)
Diazinon	0.002	HC (1986b)						
Dicamba	0.0125	HC (2014)						
Diclofop-methyl	0.001	HC (1987b)						
Dieldrin	0.00005	US EPA (2006)			16	US EPA (2006)	4.6	US EPA (2006)
Dimethoate	0.002	HC (2009b)						
Dinoseb	0.001	US EPA (2006)						
Diquat	0.008	HC (1989c)						
Diuron	0.0156	HC (1987c)						
Endosulfan	6.00E-03	US EPA (2006)						
Endrin	3.00E-04	US EPA (2006)						
Glyphosate	0.03	HC (1987d)						
Heptachlor epoxide	1.30E-05	US EPA (2006)			9.1	US EPA (2006)	2.6	US EPA (2006)
Lindane	3.00E-04	US EPA (2006)						
Linuron	2.00E-03	US EPA (2006)						
Malathion	0.02	HC (1986c)						
MCPA	0.012	HC (2010)						
Methoxychlor	0.005	US EPA (2006)						
Metolachlor	0.005	HC (1986d)						
Metribuzin	0.0083	HC (2021b)						
Paraquat (as dichloride)	0.001	HC (1986e)						
Phorate	0.0002	HC (1986f)						

TABLE A-7. HUMAN TOXICITY REFERENCE VALUES

	Threshold TRV				Non-Threshold TRV			
	Oral TDI	Source	Inhalation TC	Source	Oral SF	Source	Inhalation UR	Source
	mg/kg-d		mg/m3		(mg/kg-d)-1		(mg/m3)-1	
Picloram	0.02	HC (1990)						
Simazine	0.0013	HC (1986g)						
Tebuthiuron	7.00E-02	US EPA (2006)						
Terbufos	0.00005	HC (1995b)						
Toxaphene					1.1	US EPA (2006)	0.32	US EPA (2006)
Triallate	1.30E-02	US EPA (2006)						
Trifluralin	0.0048	HC (1992a)						
Other Organics								
Aniline	0.007	HC (1996)	0.001	HC (2017)				
Di- <i>n</i> -butyl phthalate	0.063	HC (1996)	0.28191	see note 1				
Dichlorobenzidine					0.45	US EPA (2006)	0.1	see note 1
Diethanolamine	0.005	AENV (2010a)						
Diethylene glycol	0.5	AENV (2010b)						
Diisopropanolamine	0.39	CCME (2006b)						
Ethylene glycol	2	US EPA (2006)	8.94937	see note 1				
Hexachlorobutadiene					0.078	US EPA (2006)	0.022	US EPA (2006)
Methanol	2.0	CCME (2017)	20	CCME (2017)				
Methylmethacrylate	1.4	US EPA (2006)	0.7	US EPA (2006)				
Monoethanolamine	0.05	AENV (2010a)						
MTBE	0.01	HC (1996)	0.037	HC (1996)				
Nonylphenol								
Perfluorooctane sulfonate (PFOS)	0.000065	CCME (2021a)						
Perfluorooctanoic acid (PFOA)	0.000021	CCME (2021a)						
Phenol	0.06	CCME (1997)	0.26848	see note 1				

TABLE A-7. HUMAN TOXICITY REFERENCE VALUES

	Threshold TRV			Non-Threshold TRV				
	Oral TDI	Source	Inhalation TC	Source	Oral SF	Source	Inhalation UR	Source
	mg/kg-d		mg/m ³		(mg/kg-d) ⁻¹		(mg/m ³) ⁻¹	
Sulfolane	0.0097	CCME (2006c)						
Triethylene glycol	5.0	AENV (2010b)						

Notes:

TRV = toxicity reference value

TDI = tolerable daily intake

TC = tolerable concentration

SF = slope factor

UR = unit risk

HC = Health Canada

¹ Estimated from the oral TDI assuming an adult body weight of 70.7 kg, and an inhalation rate of 15.8 m³/d.

² Human ingestion and dermal contact guideline for agricultural, residential/parkland and commercial land uses based on 10% of estimated daily intake rather than TDI. Human inhalation guidelines calculated separately. See CCME (2015).

TABLE A-8. HUMAN ABSORPTION FACTORS

	Absorption Factors					
	Gut	Source	Skin	Source	Lung	Source
Metals						
Arsenic (inorganic)	1.00		0.03	HC (2021a)	1.00	
Barite-barium	1.00		0	AENV (2009)	1.00	
Boron	1.00		0	AEP (2016c)	1.00	
Nickel	1.00		0.09	HC (2021a)	1.00	
Hydrocarbons						
Benzene	1.00		0.03	HC (2021a)	1.00	
Toluene	1.00		0.03	HC (2021a)	1.00	
Ethylbenzene	1.00		0.03	HC (2021a)	1.00	
Xylenes	1.00		0.03	HC (2021a)	1.00	
Styrene	1.00		0.03	HC (2021a)	1.00	
Aliphatic C ₆ -C ₈	1.00		0.03	HC (2021a)	1.00	
Aliphatic C _{>8} -C ₁₀	1.00		0.03	HC (2021a))	1.00	
Aliphatic C _{>10} -C ₁₂	1.00		0.20	CCME (2008a)	1.00	
Aliphatic C _{>12} -C ₁₆	1.00		0.20	CCME (2008a)	1.00	
Aliphatic C _{>16} -C ₂₁	1.00		0.20	CCME (2008a)	1.00	
Aliphatic C _{>21} -C ₃₄	1.00		0.20	CCME (2008a)	1.00	
Aliphatic C _{>34}	1.00		0.20	CCME (2008a)	1.00	
Aromatic C _{>8} -C ₁₀	1.00		0.03	HC (2021a)	1.00	
Aromatic C _{>10} -C ₁₂	1.00		0.20	CCME (2008a)	1.00	
Aromatic C _{>12} -C ₁₆	1.00		0.20	CCME (2008a)	1.00	
Aromatic C _{>16} -C ₂₁	1.00		0.20	CCME (2008a)	1.00	
Aromatic C _{>21} -C ₃₄	1.00		0.20	CCME (2008a)	1.00	
Aromatic C _{>34}	1.00		0.20	CCME (2008a)	1.00	
Naphthalene	1.00		0.03	HC (2021a)	1.00	

TABLE A-8. HUMAN ABSORPTION FACTORS

	Absorption Factors					
	Gut	Source	Skin	Source	Lung	Source
Acenaphthene	1.00		0.148	HC (2021a)	1.00	
Fluorene	1.00		0.148	HC (2021a)	1.00	
Fluoranthene	1.00		0.148	HC (2021a))	1.00	
Anthracene	1.00		0.148	HC (2021a)	1.00	
Pyrene	1.00		0.148	HC (2021a)	1.00	
Benzo(a)pyrene	1.00		0.148	HC (2021a)	1.00	
Halogenated Aliphatics						
Vinyl chloride	1.00		0.03	HC (2021a)	1.00	
1,1-Dichloroethene	1.00		0.03	HC (2021a)	1.00	
Trichloroethene (Trichloroethylene, TCE)	1.00		0.03	HC (2021a)	1.00	
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	1.00		0.03	HC (2021a)	1.00	
1,2-Dichloroethane	1.00		0.03	HC (2021a)	1.00	
Dichloromethane (Methylene chloride)	1.00		0.03	HC (2021a)	1.00	
Trichloromethane (Chloroform)	1.00		0.03	HC (2021a)	1.00	
Tetrachloromethane (Carbon tetrachloride)	1.00		0.03	HC (2021a)	1.00	
Dibromochloromethane	1.00		0.03	HC (2021a)	1.00	
Chlorinated Aromatics						
Chlorobenzene	1.00		0.03	HC (2021a)	1.00	
1,2-Dichlorobenzene	1.00		0.03	HC (2021a)	1.00	
1,4-Dichlorobenzene	1.00		0.03	HC (2021a)	1.00	
1,2,3-Trichlorobenzene	1.00		0.03	HC (2021a)	1.00	
1,2,4-Trichlorobenzene	1.00		0.03	HC (2021a)	1.00	
1,3,5-Trichlorobenzene	1.00		0.03	HC (2021a)	1.00	
1,2,3,4-Tetrachlorobenzene	1.00		0.03	HC (2021a)	1.00	
1,2,3,5-Tetrachlorobenzene	1.00		0.03	HC (2021a)	1.00	
1,2,4,5-Tetrachlorobenzene	1.00		1.00		1.00	

TABLE A-8. HUMAN ABSORPTION FACTORS

	Absorption Factors					
	Gut	Source	Skin	Source	Lung	Source
Pentachlorobenzene	1.00		1.00		1.00	
Hexachlorobenzene	1.00		1.00		1.00	
Dichlorophenol	1.00		0.03	HC (2021a)	1.00	
Trichlorophenol	1.00		0.03	HC (2021a)	1.00	
Tetrachlorophenol	1.00		0.03	HC (2021a)	1.00	
Pentachlorophenol	1.00		1.00		1.00	
Dioxins and Furans	1.00		0.03	HC (2021a)	1.00	
PCBs	1.00		0.14	HC (2021a)	1.00	
Pesticides						
Aldicarb	1.00		1.00		1.00	
Aldrin and dieldrin	1.00		1.00		1.00	
Atrazine and metabolites	1.00		1.00		1.00	
Azniphos-methyl (Guthion)	1.00		1.00		1.00	
Bromacil	1.00		1.00		1.00	
Bromoxynil	1.00		1.00		1.00	
Carbaryl	1.00		1.00		1.00	
Carbofuran	1.00		1.00		1.00	
Chlorothalonil	1.00		1.00		1.00	
Chlorpyrifos	1.00		1.00		1.00	
2,4-D	1.00		0.03	HC (2021a)	1.00	
DDT	1.00		1.00		1.00	
Diazinon	1.00		1.00		1.00	
Dicamba	1.00		1.00		1.00	
Diclofop-methyl	1.00		0.03	HC (2021a)	1.00	
Dieldrin (see Aldrin and Dieldrin)	1.00		1.00		1.00	
Dimethoate	1.00		0.03	HC (2021a)	1.00	
Dinoseb	1.00		1.00		1.00	

TABLE A-8. HUMAN ABSORPTION FACTORS

	Absorption Factors					
	Gut	Source	Skin	Source	Lung	Source
Diquat	1.00		1.00		1.00	
Diuron	1.00		1.00		1.00	
Endosulfan	1.00		0.03	HC (2021a)	1.00	
Endrin	1.00		1.00		1.00	
Glyphosate	1.00		1.00		1.00	
Heptachlor epoxide	1.00		1.00		1.00	
Lindane	1.00		1.00		1.00	
Linuron	1.00		1.00		1.00	
Malathion	1.00		1.00		1.00	
MCPA	1.00		1.00		1.00	
Methoxychlor	1.00		1.00		1.00	
Metolachlor	1.00		1.00		1.00	
Metribuzin	1.00		1.00		1.00	
Paraquat (as dichloride)	1.00		1.00		1.00	
Phorate	1.00		1.00		1.00	
Picloram	1.00		1.00		1.00	
Simazine	1.00		1.00		1.00	
Tebuthiuron	1.00		1.00		1.00	
Terbufos	1.00		1.00		1.00	
Toxaphene	1.00		1.00		1.00	
Triallate	1.00		0.03	HC (2021a)	1.00	
Trifluralin	1.00		0.03	HC (2021a)	1.00	
Other Organics						
Aniline	1.00		0.03	HC (2021a)	1.00	
Di- <i>n</i> -butyl phthalate	1.00		1.00		1.00	
Dichlorobenzidine	1.00		1.00		1.00	
Diethanolamine	1.00		1.00		1.00	

TABLE A-8. HUMAN ABSORPTION FACTORS

	Absorption Factors					
	Gut	Source	Skin	Source	Lung	Source
Diethylene glycol	1.00		1.00		1.00	
Diisopropanolamine	1.00		0.03	HC (2021a)	1.00	
Ethylene glycol	1.00		0.03	HC (2021a)	1.00	
Hexachlorobutadiene	1.00		0.03	HC (2021a)	1.00	
Methanol	1.00		0.03	HC (2021a)	1.00	
Methylmethacrylate	1.00		0.03	HC (2021a)	1.00	
Monoethanolamine	1.00		1.00		1.00	
MTBE	1.00		0.03	HC (2021a)	1.00	
Nitriloacetic acid	1.00		1.00		1.00	
Nonylphenol	1.00		1.00		1.00	
Perfluorooctane sulfonate (PFOS)	1.00		0.10	CCME (2021)	1.00	
Phenol	1.00		0.03	HC (2021a)	1.00	
Sulfolane	1.00		1.00		1.00	
Triethylene glycol	1.00		1.00		1.00	

Notes:

Sources only provided where an absorption factor other than 1.0 is used.

Dermal absorption factors for compounds with a boiling point >250°C are considered volatile for the purposes of dermal absorption. Dermal absorption factors for these compounds are set to 0.03 (HC, 2021a).

CCME (1999) refers to the Canadian Environmental Quality Guidelines (CEQG) and updates, including the scientific supporting documents that are summarized in the CEQG.

HC = Health Canada

TABLE A-9. HUMAN BACKGROUND EXPOSURE PARAMETERS

	Toddler EDI	Adult EDI	Source	Ca	Source	BSC	Source	SAF
	mg/kg-d	mg/kg-d		mg/m3		mg/kg		
Metals								
Arsenic (inorganic)	na	na	CCME (1999)	na	CCME (1999)	10	CCME (1999)	0.2
Barite-barium	0.014	0.014	AENV (2009)	na	AENV (2009)	325	AENV (2009)	0.25
Boron	0.048	0.018	AEP (2016c)	na	AEP (2016c)	10	AEP (2016c)	0.25
Nickel	0.0106	0.0038	CCME (2015)	na	-	26.8	CCME (2015)	0.2
Hydrocarbons								
Benzene	na	na	-	na	-	0	assumed	na
Toluene	0.0028	0.0028	EC (2004b)	0.0442	EC (2004b)	0	assumed	0.5
Ethylbenzene	0.0029	0.0029	EC (2004b)	0.0075	EC (2004b)	0	assumed	0.5
Xylenes	0.0079	0.0079	EC (2004b)	0.00182	EC (2004b)	0	assumed	0.5
Styrene	0.00071	0.00027	PSL	0.00028	PSL	0	assumed	0.5
Aliphatic C ₆ -C ₈	0.02334	0.02334	CCME (2008a)	0.09111	CCME (2008a)	0	assumed	0.5
Aliphatic C _{>8} -C ₁₀	0.0103	0.0103	CCME (2008a)	0.03881	CCME (2008a)	0	assumed	0.5
Aliphatic C _{>10} -C ₁₂	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.5
Aliphatic C _{>12} -C ₁₆	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.5
Aliphatic C _{>16} -C ₂₁	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.6
Aliphatic C _{>21} -C ₃₄	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.6
Aliphatic C _{>34}	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.8
Aromatic C _{>8} -C ₁₀	0.00938	0.00938	CCME (2008a)	0.03745	CCME (2008a)	0	assumed	0.5
Aromatic C _{>10} -C ₁₂	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.5
Aromatic C _{>12} -C ₁₆	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.5
Aromatic C _{>16} -C ₂₁	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.6
Aromatic C _{>21} -C ₃₄	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.6
Aromatic C _{>34}	0	0	CCME (2008a)	0	CCME (2008a)	0	assumed	0.8
Naphthalene	0.000535	0.00021231	ATSDR (2005)	0.00095	ATSDR (2005)	0	assumed	0.5

TABLE A-9. HUMAN BACKGROUND EXPOSURE PARAMETERS

	Toddler EDI	Adult EDI	Source	Ca	Source	BSC	Source	SAF
	mg/kg-d	mg/kg-d		mg/m3		mg/kg		
Acenaphthene	0	0	assumed	0	assumed	0	assumed	0.5
Fluorene	0.00902	0.00358	ATSDR (1995)	0.016	ATSDR (1995)	0	assumed	0.5
Fluoranthene	0	0	assumed	0	assumed	0	assumed	0.5
Anthracene	0.00502	0.00199	ATSDR (1995)	0.0089	ATSDR (1995)	0	assumed	0.5
Pyrene	0.00620	0.00246	ATSDR (1995)	0.011	ATSDR (1995)	0	assumed	0.5
Benzo(a)pyrene	0.0000059	0.0000059	CCME (2010)	na	-	0.07	CCME (2010)	0.5
Halogenated Aliphatics								
Vinyl chloride	0	0	assumed	0	assumed	0	assumed	0.2
1,1-Dichloroethene	0	0	assumed	0	assumed	0	assumed	0.2
Trichloroethene (Trichloroethylene)	0.00053	0.00041	CCME (2007)	0.0014	CCME (2007)	0	assumed	0.2
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	0	0	assumed	0	assumed	0	assumed	0.2
1,2-Dichloroethane	0.0006	0.0005	PSL	0.0018	PSL	0	assumed	0.2
Dichloromethane (Methylene chloride)	0.00558	0.00471	PSL	0.0063	PSL	0	assumed	0.2
Trichloromethane (Chloroform)	0.004315	0.00361	PSL	0.0063	PSL	0	assumed	0.2
Tetrachloromethane (Carbon tetrachloride)	0	0	assumed	0	assumed	0	assumed	0.2
Dibromochloromethane	0	0	assumed	0	assumed	0	assumed	0.2
Chlorinated Aromatics								
Chlorobenzene	0.000122	0.000066	PSL	0.00016	PSL	0	assumed	0.2
1,2-Dichlorobenzene	0.00004	0.00003	PSL	0.1	PSL	0	assumed	0.2
1,4-Dichlorobenzene	0.0014	0.0009	PSL	0.0028	PSL	0	assumed	0.2
1,2,3-Trichlorobenzene	0.00023	0.00024	PSL	0.0008	PSL	0	assumed	0.2
1,2,4-Trichlorobenzene	0.0006	0.00045	PSL	0.0018	PSL	0	assumed	0.2
1,3,5-Trichlorobenzene	0.00032	0.00025	PSL	0.0008	PSL	0	assumed	0.2
1,2,3,4-Tetrachlorobenzene	0.0000007	0.00000025	PSL	0.00000017	PSL	0	assumed	0.2

TABLE A-9. HUMAN BACKGROUND EXPOSURE PARAMETERS

	Toddler EDI	Adult EDI	Source	Ca	Source	BSC	Source	SAF
	mg/kg-d	mg/kg-d		mg/m3		mg/kg		
1,2,3,5-Tetrachlorobenzene	0.00000045	0.00000015	PSL	0.00000017	PSL	0	assumed	0.2
1,2,4,5-Tetrachlorobenzene	0.0000007	0.0000002	PSL	0.00000017	PSL	0	assumed	0.2
Pentachlorobenzene	0.000002	0.0000005	PSL	0.0000001	PSL	0	assumed	0.2
Hexachlorobenzene	0.0000178	0.0000028	PSL	0.00000015	PSL	0	assumed	0.2
2,4-Dichlorophenol	0	0	assumed	0	assumed	0	assumed	0.2
2,4,6-Trichlorophenol	0	0	assumed	0	assumed	0	assumed	0.2
2,3,4,6-Tetrachlorophenol	0	0	assumed	0	assumed	0	assumed	0.2
Pentachlorophenol	0	0	assumed	0	assumed	0	assumed	0.2
Dioxins and Furans	7.1E-09	1.33E-09	CCME (2002)	0	assumed	0	assumed	0.25
PCBs	7.69E-06	0.00000254	EC (2001)	0	assumed	0	assumed	0.2
Pesticides								
Aldicarb	0	0	assumed	0	assumed	0	assumed	0.2
Aldrin and dieldrin	0	0	assumed	0	assumed	0	assumed	0.2
Atrazine and metabolites	0	0	assumed	0	assumed	0	assumed	0.2
Azinphos-methyl (Guthion)	0	0	assumed	0	assumed	0	assumed	0.2
Bromacil	0	0	assumed	0	assumed	0	assumed	0.2
Bromoxynil	0	0	assumed	0	assumed	0	assumed	0.2
Carbaryl	0	0	assumed	0	assumed	0	assumed	0.2
Carbofuran	0	0	assumed	0	assumed	0	assumed	0.2
Chlorothalonil	0	0	assumed	0	assumed	0	assumed	0.2
Chlorpyrifos	0	0	assumed	0	assumed	0	assumed	0.2
2,4-D	0	0	assumed	0	assumed	0	assumed	0.2
DDT	0	0	assumed	0	assumed	0	assumed	0.2
Diazinon	0	0	assumed	0	assumed	0	assumed	0.2
Dicamba	0	0	assumed	0	assumed	0	assumed	0.2

TABLE A-9. HUMAN BACKGROUND EXPOSURE PARAMETERS

	Toddler EDI	Adult EDI	Source	Ca	Source	BSC	Source	SAF
	mg/kg-d	mg/kg-d		mg/m3		mg/kg		
Diclofop-methyl	0	0	assumed	0	assumed	0	assumed	0.2
Dieldrin (see Aldrin and Dieldrin)								
Dimethoate	0	0	assumed	0	assumed	0	assumed	0.2
Dinoseb	0	0	assumed	0	assumed	0	assumed	0.2
Diquat	0	0	assumed	0	assumed	0	assumed	0.2
Diuron	0	0	assumed	0	assumed	0	assumed	0.2
Endosulfan	0	0	assumed	0	assumed	0	assumed	0.2
Endrin	0	0	assumed	0	assumed	0	assumed	0.2
Glyphosate	0	0	assumed	0	assumed	0	assumed	0.2
Heptachlor epoxide	0	0	assumed	0	assumed	0	assumed	0.2
Lindane	0	0	assumed	0	assumed	0	assumed	0.2
Linuron	0	0	assumed	0	assumed	0	assumed	0.2
Malathion	0	0	assumed	0	assumed	0	assumed	0.2
MCPA	0	0	assumed	0	assumed	0	assumed	0.2
Methoxychlor	0	0	assumed	0	assumed	0	assumed	0.2
Metolachlor	0	0	assumed	0	assumed	0	assumed	0.2
Metribuzin	0	0	assumed	0	assumed	0	assumed	0.2
Paraquat (as dichloride)	0	0	assumed	0	assumed	0	assumed	0.2
Phorate	0	0	assumed	0	assumed	0	assumed	0.2
Picloram	0	0	assumed	0	assumed	0	assumed	0.2
Simazine	0	0	assumed	0	assumed	0	assumed	0.2
Tebuthiuron	0	0	assumed	0	assumed	0	assumed	0.2
Terbufos	0	0	assumed	0	assumed	0	assumed	0.2
Toxaphene	0	0	assumed	0	assumed	0	assumed	0.2
Triallate	0	0	assumed	0	assumed	0	assumed	0.2

TABLE A-9. HUMAN BACKGROUND EXPOSURE PARAMETERS

	Toddler EDI	Adult EDI	Source	Ca	Source	BSC	Source	SAF
	mg/kg-d	mg/kg-d		mg/m3		mg/kg		
Trifluralin	0	0	assumed	0	assumed	0	assumed	0.2
Other Organics								
Aniline	0	0	assumed	0	assumed	0	assumed	0.2
Di- <i>n</i> -butyl phthalate	0.005	0.0019	PSL	0.00285	PSL	0	assumed	0.2
Dichlorobenzidine	0	0	assumed	0	assumed	0	assumed	0.2
Diethanolamine	0	0	assumed	0	assumed	0	assumed	0.25
Diethylene glycol	0	0	assumed	0	assumed	0	assumed	0.25
Diisopropanolamine	0	0	assumed	0	assumed	0	assumed	0.33
Ethylene glycol	0.0344	0.0167	PSL	0	PSL	0	assumed	0.33
Hexachlorobutadiene	0.00012	0.00003	PSL	0.00006	PSL	0	assumed	0.2
Methanol	1.6	1.6	CCME (2017)	0.04	CCME (2017)	0	Assumed	0.2
Methylmethacrylate	1.13E-07	0	PSL	2.44E-07	PSL	0	assumed	0.2
Monoethanolamine	0	0	assumed	0	assumed	0	assumed	0.25
MTBE	0.00000067	0.0000005	PSL	0.0000015	PSL	0	assumed	0.2
Nonylphenol	na	na	-	na	-	0	assumed	na
Perfluorooctane sulfonate (PFOS)	0.0000038	0.0000023	CCME (2021)	na	-	0	assumed	0.2
Phenol	0	0	assumed	0	assumed	0	assumed	0.2
Sulfolane	0	0	assumed	0	assumed	0	assumed	0.33
Triethylene glycol	0	0	assumed	0	assumed	0	assumed	0.25

Notes:

na = not available or not applicable

EDI = estimated daily intake

Ca = background indoor air concentration

SAF = soil allocation factor

PSL = Priority Substance List assessment under Canadian Environmental Protection Act (CEPA) for corresponding substance.

CCME (1999) refers to the Canadian Environmental Quality Guidelines (CEQG) and updates, including the scientific supporting documents that are summarized in the CEQG.

TABLE A-10. PETROLEUM HYDROCARBON SUBFRACTION DISTRIBUTION

Soil				
TPH Sub-fraction (Proportion of Total Fraction Mass)				
Fraction	Fraction 1	Fraction 2	Fraction 3	Fraction 4
Aliphatics				
C6-C8	0.55			
C>8-C10	0.36			
C>10-C12		0.36		
C>12-C16		0.44		
C>16-C21			0.56	
C>21-C34			0.24	
C>34				0.8
Aromatics				
C>7-C8				
C>8-C10	0.09			
C>10-C12		0.09		
C>12-C16		0.11		
C>16-C21			0.14	
C>21-C34			0.06	
C>34				0.2
Sum of all subfractions	1	1	1	1
Groundwater				
TPH Sub-fraction (Proportion of Total Fraction Mass)				
Fine Soil		Coarse Soil		
Fraction	Fraction 1	Fraction 2	Fraction 1	Fraction 2
Aliphatics				
C6-C8	0.5768		0.6047	
C>8-C10	0.0663		0.0632	
C>10-C12		0.0239		0.024
C>12-C16		0.0015		0.0015
Aromatics				
C>7-C8				
C>8-C10	0.3569		0.3321	
C>10-C12		0.6029		0.6034
C>12-C16		0.3718		0.3711
Sum of all subfractions	1	1	1	1

TABLE A-11. SURFACE WATER QUALITY GUIDELINES

	Drinking Water	Aquatic Life	Irrigation	Livestock Water	Wildlife Water	DTED ¹
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/kg-bw/d)
General and Inorganic Parameters						
Aluminum	2.9	see note 2	5	5		
Ammonia		see note 2				
Bromate	0.01					
Chloride	250	120	100			
Cyanide (free)	0.2	0.0052				
Electrical Conductivity (dS/m)			1			
Fluoride	1.5		1	1		
Nitrate (as nitrogen)	10	3				
Nitrate + Nitrite (as nitrogen)				100		
Nitrite (as nitrogen)	1.0	see note 2		10		
Sodium	200					
Sodium Adsorption Ratio (SAR)			5			
Sulphate	500	see note 2		1000		
Sulphide - Total (as S) ³	0.05	0.002				
Total Dissolved Solids (TDS)	500		500	3000		
Metals						
Antimony	0.006					
Arsenic (inorganic)	0.01	0.005	0.16	0.025		
Barium	2.0					
Boron	5	1.5	1.0	5		
Cadmium	0.007	see note 2	0.0082	0.08		
Chromium (trivalent)		0.0089	0.0049	0.05		
Chromium (hexavalent)		0.001	0.008	0.05		
Chromium (total) ⁸	0.05					
Copper	1	0.007	0.2	0.5		
Iron	0.3	0.3	5			

TABLE A-11. SURFACE WATER QUALITY GUIDELINES

	Drinking Water	Aquatic Life	Irrigation	Livestock Water	Wildlife Water	DTED ¹
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/kg-bw/d)
Lead	0.005	see note 2	0.2	0.1		
Manganese	0.02		0.2			
Mercury (total) ⁸	0.001	0.000005		0.003		
Nickel		see note 2	0.2	1		
Selenium	0.05	0.002	0.02	0.05		
Silver		0.0001	0.02	0.05		
Uranium	0.02	0.015	0.01	0.2		
Zinc	5	0.03	1	50		
Hydrocarbons						
Benzene	0.005	0.04		0.088	0.076	0.08
Toluene	0.024	0.0005		4.91	4.25	4.46
Ethylbenzene	0.0016	0.09		3.20	2.77	2.91
Xylenes	0.02	0.03		13.1	11.3	11.9
Styrene	2.8	0.072				
Aliphatic C ₆ -C ₈	140	0.047		53.6	46.4	48.72
Aliphatic C _{>8} -C ₁₀	2.5	0.0076		53.6	46.4	48.72
Aromatic C _{>8} -C ₁₀	0.84	0.14		53.6	46.4	48.72
F1		see note 4		53.6	46.4	48.72
Aliphatic C _{>10} -C ₁₂	2.75	0.0012		49.2	42.6	44.73
Aliphatic C _{>12} -C ₁₆	2.75	0.000074		49.2	42.6	44.73
Aromatic C _{>10} -C ₁₂	1.1	0.096		49.2	42.6	44.73
Aromatic C _{>12} -C ₁₆	1.1	0.055		49.2	42.6	44.73
F2		see note 4		49.2	42.6	44.73
F3				79.7	69.0	72.45
F4				42.0	36.4	38.22
Acenaphthene	1.414	0.0058		NGR	NGR	70
Anthracene	7.07	0.000012		NGR	NGR	200
Fluoranthene	0.94	0.00004		NGR	NGR	50

TABLE A-11. SURFACE WATER QUALITY GUIDELINES

	Drinking Water	Aquatic Life	Irrigation	Livestock Water	Wildlife Water	DTED ¹
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/kg-bw/d)
Fluorene	0.94	0.003		NGR	NGR	50
Naphthalene	0.47	0.001		NGR	NGR	28.6
Phenanthrene		0.0004		NGR	NGR	140
Pyrene	0.71	0.000025		NGR	NGR	25
Benz[a]anthracene		0.000018		NGR	NGR	20
Benzo[b+j]fluoranthene				NGR	NGR	20
Benzo[k]fluoranthene				NGR	NGR	20
Benzo[g,h,i]perylene						
Benzo[a]pyrene	0.00004	0.000015		NGR	NGR	2
Chrysene				NGR	NGR	20
Dibenz[a,h]anthracene						
Indeno[1,2,3-c,d]pyrene						
Halogenated Aliphatics						
Vinyl chloride	0.002					
1,1-Dichloroethene	0.014					
Trichloroethene (Trichloroethylene, TCE)	0.005	0.021		0.05		
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	0.010	0.111				
1,2-Dichloroethane	0.005	0.1		0.005		
Dichloromethane (Methylene chloride)	0.05	0.098		0.05		
Trichloromethane (Chloroform) ⁷	0.08	0.0018		0.1		
Tetrachloromethane (Carbon tetrachloride)	0.002	0.0133		0.005		
Dibromochloromethane	0.189			0.1		
Chlorinated Aromatics						
Chlorobenzene	0.03	0.0013				
1,2-Dichlorobenzene	0.003	0.0007				
1,3-Dichlorobenzene		0.15				

TABLE A-11. SURFACE WATER QUALITY GUIDELINES

	Drinking Water	Aquatic Life	Irrigation	Livestock Water	Wildlife Water	DTED ¹
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/kg-bw/d)
1,4-Dichlorobenzene	0.001	0.026				
1,2,3-Trichlorobenzene	0.014	0.008				
1,2,4-Trichlorobenzene	0.015	0.024				
1,3,5-Trichlorobenzene	0.014					
1,2,3,4-Tetrachlorobenzene	0.032	0.0018				
1,2,3,5-Tetrachlorobenzene	0.0038					
1,2,4,5-Tetrachlorobenzene	0.0020					
Pentachlorobenzene	0.0094	0.006				
Hexachlorobenzene	0.000568			0.00052		
2,4-Dichlorophenol	0.0003	0.0002				
2,4,6-Trichlorophenol	0.002	0.018				
2,3,4,6-Tetrachlorophenol	0.001	0.001				
Pentachlorophenol	0.03	0.0005				
Dioxins and Furans	2.7E-08					
PCBs	0.000094					
Pesticides						
Aldicarb	0.009	0.001	0.073	0.011		
Aldrin	0.000028					
Atrazine and metabolites	0.005	0.0018	0.01	0.005		
Azinphos-methyl (Guthion)	0.02	0.00001				
Bromacil ⁵	0.95	0.005	0.0002	1.1		
Bromoxynil	0.005	0.005	0.00044	0.011		
Carbaryl	0.09	0.0002		1.1		
Carbofuran	0.09	0.0018		0.045		
Chlorothalonil	0.14	0.00018	0.0093	0.17		
Chlorpyrifos	0.09	0.000002		0.024		
2,4-D	0.1	0.004		0.1		
DDT	0.0014					

TABLE A-11. SURFACE WATER QUALITY GUIDELINES

	Drinking Water	Aquatic Life	Irrigation	Livestock Water	Wildlife Water	DTED ¹
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/kg-bw/d)
Diazinon	0.02	0.00017				
Dicamba	0.12	0.01	0.000008	0.122		
Diclofop-methyl	0.009	0.0061	0.00024	0.009		
Dieldrin	0.000029					
Dimethoate	0.02	0.0062		0.003		
Dinoseb	0.01	0.00005	0.021	0.15		
Diquat	0.07					
Diuron	0.15					
Endosulfan	0.057	0.000003				
Endrin	0.0028					
Glyphosate	0.28	0.065		0.28		
Heptachlor epoxide	0.000052					
Lindane	0.0028	0.00001		0.004		
Linuron	0.019	0.007	0.00011			
Malathion	0.19	0.0001				
MCPA	0.1	0.0026	0.00004	0.025		
Methoxychlor	0.9	0.00003				
Metolachlor	0.05	0.0078	0.028	0.05		
Metribuzin	0.08	0.001	0.0005	0.08		
Paraquat (as dichloride)	0.01					
Phorate	0.002					
Picloram	0.19	0.029		0.19		
Simazine	0.01	0.01	0.0005	0.01		
Tebuthiuron	0.66	0.0016	0.00043	0.13		
Terbufos	0.001					
Toxaphene	0.00043					
Triallate	0.123	0.00024		0.23		
Trifluralin	0.045	0.0002		0.045		

TABLE A-11. SURFACE WATER QUALITY GUIDELINES

	Drinking Water	Aquatic Life	Irrigation	Livestock Water	Wildlife Water	DTED ¹
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/kg-bw/d)
Other Organics						
Aniline	0.066	0.0022				
Di- <i>n</i> -butyl phthalate	0.59	0.019				
Dichlorobenzidine	0.001					
Diethanolamine	0.06	0.45				
Diethylene glycol	6.0	150				
Diisopropanolamine	3.6	1.6	3.2			
Ethylene glycol	31	190				
Hexachlorobutadiene	0.006	0.0013				
Methanol ⁶	19	23				
Methylmethacrylate	13					
Monoethanolamine	0.6	0.075				
MTBE	0.015	10				
Nitriloacetic acid	0.4					
Nonylphenol + ethoxylates		0.0066				
Perfluorooctane sulfonate (PFOS)	0.0006	0.0068		0.060	0.052	0.0543
Perfluorooctanoic acid (PFOA)	0.0002					
Phenol	0.57	0.004		0.002		
Sulfolane	0.09	50	0.8			
Triethylene glycol	60	350				
Trihalomethanes - total (THMs)	0.1					

TABLE A-11. SURFACE WATER QUALITY GUIDELINES**Notes:**

See text for guideline sources.

¹ DTED = daily threshold effect dose from CCME (1999, 2008a, 2021). Included where used to calculate livestock and wildlife watering guidelines according to:

$$WQG = \frac{DTED \times BW \times AF}{WIR}$$

Where:

WQG	=	water quality guideline (mg/L)
DTED	=	daily threshold effect dose (mg/kg-bw/d)
BW	=	body weight (kg)
AF	=	allocation factor of 0.2 (unitless)
WIR	=	water ingestion rate (L/d)

² See Environmental Quality Guidelines for Alberta Surface Waters (ESRD, 2014).

³ Surface water guidelines based on H₂S toxicity but guidelines may be applied to total sulphide measurements.

⁴ Aquatic life guidelines for direct application to surface water are found in Environmental Quality Guidelines for Alberta Surface Waters (ESRD, 2014). F1 and F2 subfraction guidelines are used to calculate soil and groundwater guidelines for the protection of aquatic life.

⁵ Drinking water guideline calculated from Reference Dose (USEPA 1996b).

⁶ Source guidance values for drinking water and aquatic life from CCME (2017).

⁷ Source guidance value from health based target presented in HC (2006).

⁸ Total means all chemical species.

NGR - no guideline required, calculated value > solubility

Appendix B Influence of Parameters on Guideline Values for Various Exposure Pathways

The key model parameters that affect Tier 2 objectives are highly dependent on the governing pathway. The following section highlights the key Tier 2 adjustable model parameters affecting each of the exposure pathways. A summary of the influence of key parameters is presented in Table B-1. Further considerations for individual model parameters, including measurement methods/locations, are discussed in Appendix C. The proponent is obligated to consider all site characteristics at Tier 2, and not just those which would result in higher Tier 2 objectives, and that several groups of parameters must always be measured together, as discussed in Appendix C.

Tier 2 Soil Objectives

Human Direct Contact (soil ingestion, dermal contact and particulate inhalation)

Guidelines for the human direct soil contact pathway cannot be adjusted at Tier 2 since they are affected only by the exposure scenario, receptor characteristics and chemical properties, none of which can be modified for Tier 2 closure.

Vapour Inhalation

Key parameters affecting vapour inhalation include the soil vapour permeability, soil organic carbon content, soil moisture content and depth to contamination. Increasing soil vapour permeability leads to lower Tier 2 objectives; higher values for the other three parameters lead to higher Tier 2 objectives. Soil bulk density has a moderate effect as well, with higher bulk density (and therefore lower total soil porosity) generally leading to higher Tier 2 objectives.

Of particular concern for the vapour inhalation pathway are very permeable soils such as well-sorted gravels beneath buildings, or buildings without concrete foundation slabs. If either of these situations occurs, the Tier 1 objectives may not be protective and a Tier 2 assessment is required.

Soil moisture is difficult to modify because of temporal variability and spatial variability in moisture content. This leads to requirements for long term in situ monitoring to capture spatial and temporal variabilities. See Appendix C for further details.

Protection of Potable Water and Livestock/Irrigation Water

The protection of potable water and livestock/irrigation watering are all based on the protection of an aquifer assumed to be in contact with the contamination at Tier 1. These pathways are strongly affected by the soil organic carbon fraction, with a higher organic carbon resulting in higher Tier 2 objectives. The presence of vertical separation between the contamination and the groundwater aquifer also results in higher Tier 2 objectives. The saturated hydraulic conductivity and hydraulic gradient have a moderate effect on this pathway, with higher values of these parameters resulting in higher Tier 2 objectives. The source length (parallel to the direction of groundwater flow) has a moderate effect, with larger sources resulting in lower Tier 2 objectives. Soil bulk density has a smaller effect on these pathways, with higher bulk density resulting in lower Tier 2 levels in the absence of an offset distance. For scenarios with a lateral offset between the source and receptor, parameter influences are as for the aquatic life and wildlife watering pathways (below). In the case of a Domestic Use Aquifer, a lateral offset between the contamination and existing water user cannot be applied at Tier 2 (the entire aquifer is considered to be the point of compliance). See Appendix E for a description of a Domestic Use Aquifer.

The Tier 1 objectives may not be protective of soils with low organic carbon content or very coarse materials, such as well sorted gravels. A Tier 2 assessment is required in these cases. Source areas that are significantly larger than the default values also require a Tier 2 assessment or site-specific risk assessment.

Protection of Groundwater for Aquatic Life and Wildlife Watering

The protection of groundwater for aquatic life and for wildlife watering differ from the other groundwater pathways due to the presence of an assumed offset to a fixed surface water body. The effect of the organic carbon fraction is similar to the other groundwater pathways. Saturated hydraulic conductivity and hydraulic gradient have a very strong effect on these pathways, with higher values for these parameters resulting in lower Tier 2 objectives. The distance to the surface water body also has a large effect for contaminants that are known to biodegrade in the subsurface, with greater distances resulting in larger Tier 2 objectives. Increased source length (parallel to groundwater flow) results in lower Tier 2 objectives; increasing soil bulk density results in slightly higher Tier 2 objectives.

The Tier 1 objectives may not be protective of soils with low organic carbon content or high saturated hydraulic conductivity such as well sorted gravels or high hydraulic gradients, and a Tier 2 assessment is required in these cases. Sources that are significantly larger than the default scenario also require a Tier 2 assessment.

Ingestion of Produce, Meat and Dairy

The ingestion of produce, meat and dairy by humans cannot be adjusted at Tier 2 at this time.

Ecological Soil Contact

The ecological soil contact pathway cannot normally be adjusted. For a select number of compounds, it may be possible to evaluate ecological soil contact at Tier 2 Site Specific Risk Assessment.

Livestock/Wildlife Soil and Food Ingestion

The livestock and wildlife soil and food ingestion pathways cannot be adjusted in the model at this time.

Offsite Migration

The offsite migration pathway cannot be adjusted at Tier 2. However, it only applies if there are more sensitive properties in the vicinity of the site.

Management Levels

Management levels, when specified, cannot be adjusted or excluded.

Tier 2 Groundwater Objectives

Vapour Inhalation

The vapour inhalation pathway is strongly affected by the soil vapour permeability, with higher vapour permeability resulting in lower Tier 2 objectives. The depth to groundwater can also have a significant effect, with a greater depth to groundwater resulting in higher Tier 2 objectives. Shallow groundwater in contact with a building or where high water table conditions or the capillary fringe may lead to contact with the building leads to a requirement for a site-specific risk assessment. Alternatively, it is permissible to use a risk-based value in these cases based on a 0.01 attenuation coefficient (dilution factor of 100), rather than a calculated dilution factor for the building similar to cases where contamination is within 30 cm of the building (see Appendix C, Section C.7).

Higher soil bulk density and soil moisture content also lead to higher Tier 2 objectives.

As for soil guidelines for this pathway, the presence of high permeability soils or buildings without concrete foundations requires a Tier 2 assessment. Presence or potential presence of receptors that are more sensitive than the standard land use definition generally requires a Tier 2 re-evaluation but often can be dealt with by choosing a more sensitive land use definition at Tier 1 where those receptors are allowed.

Potable Water and Livestock/Irrigation Water

Groundwater objectives for the protection of potable water, livestock water and irrigation water cannot normally be adjusted at Tier 2, since the point of compliance is the entire aquifer for these pathways. However, it may be appropriate to apply the livestock and irrigation water pathways with an offset distance at Tier 2 if the subject site is not agricultural but there are agricultural properties downgradient – in this case the guidelines for these pathways are calculated in a similar manner to the aquatic life and wildlife watering pathways (below).

Aquatic Life and Wildlife Watering

The aquatic life and wildlife watering pathways are strongly affected by the distance to the surface water body, saturated hydraulic conductivity and hydraulic gradient. Increasing the distance to surface water results in higher Tier 2 objectives for chemicals where a saturated zone degradation rate is specified. Increasing the hydraulic conductivity and hydraulic gradient results in lower Tier 2 objectives. The organic carbon content in the saturated zone affects the sorption of organic compounds; higher organic carbon content may result in an increase in Tier 2 objectives particularly for higher K_{oc} compounds. The soil dry bulk density also influences these pathways; a higher bulk density (and therefore a lower soil porosity) results in higher Tier 2 objectives.

Management Limits

Management limits, when specified, cannot be modified or eliminated at Tier 2.

Chemical-Specific Considerations

In some cases model parameters may have a greater or lesser influence on particular groups of chemicals. For pathways involving lateral groundwater transport, the model is relatively insensitive to changes where biodegradation is not allowed. Biodegradation rates are provided in Table A-6 for certain chemicals considered to have sufficient data available. Tier 1 guidelines have been established for other substances that may also biodegrade, but where AEP has not specified biodegradation rates. Incorporation of a biodegradation component into the Tier 2 model for these substances is not permitted. It may be possible to use a site-specific approach in these instances that incorporates a combination of long term monitoring and modeling to determine risk to receptors with adequate supporting data from the site.

TABLE B-1 INFLUENCE OF TIER 2 ADJUSTABLE AND MEASURABLE PARAMETERS ON SOIL OBJECTIVES

Tier 2 Objective Type	Exposure Pathway or Receptor	Parameter										
		Soil Vapour Permeability	Soil Moisture Content	Soil Bulk Density	Organic Carbon Fraction	Hydraulic Conductivity	Hydraulic Gradient	Source Length	Depth to Contamination ^a	Depth to Groundwater ^b	Distance to Receptors ^c	Additional Comments
Soil Objectives	Direct Contact	-	-	-	-	-	-	-	-	-	-	d
	Vapour inhalation	↓↓	↑↓	↑↓	↑↑	-	-	-	↑↑	-	-	
	Potable Water	-	↑↓	↑↓	↑↑	↑ ^e	↑ ^e	↓	-	-	↑↑ ^f	
	Livestock watering	-	↑↓	↑↓	↑↑	↑ ^e	↑ ^e	↓	-	-	↑↑ ^f	
	Aquatic life	-	↑↓	↑↓	↑↑	↓↓ ^f	↓↓ ^f	↓	-	-	↑↑ ^f	
	Wildlife watering	-	↑↓	↑↓	↑↑	↓↓ ^f	↓↓ ^f	↓	-	-	↑↑ ^f	
	Eco Soil Ingestion	-	-	-	-	-	-	-	-	-	-	d
	Eco Soil Contact	-	-	-	-	-	-	-	-	-	-	d
	Offsite Migration	-	-	-	-	-	-	-	-	-	-	d
	Management Level	-	-	-	-	-	-	-	-	-	-	d
Groundwater Objectives	Vapour inhalation	↓↓	↑	↑	-	-	-	-	-	↑↑	-	
	Potable Water	-	-	-	-	-	-	-	-	-	↑↑ ^f	
	Livestock watering	-	-	-	-	-	-	-	-	-	↑↑ ^f	
	Aquatic life ^e	-	-	↑	-	↓↓ ^f	↓↓ ^f	-	-	-	↑↑ ^f	
	Wildlife watering ^e	-	-	↑	-	↓↓ ^f	↓↓ ^f	-	-	-	↑↑ ^f	
	Management Level ^d	-	-	-	-	-	-	-	-	-	-	d

- ↑↑ strongly influential; increasing the parameter increases the Tier 2 guideline
- ↑ somewhat influential; increasing the parameter increases the Tier 2 guideline
- ↓↓ strongly influential; increasing the parameter decreases the Tier 2 guideline
- ↓ somewhat influential; increasing the parameter decreases the Tier 2 guideline
- ↑↓ parameter may slightly increase or decrease Tier 2 guidelines, depending on other parameters
- no influence

^a parameter only has significant influence if unsaturated zone transport occurs
^b parameter only has significant influence if depth to contamination is greater than slab/basement depth
^c may result in land/water use restriction
^d pathway is not available for Tier 2 Guideline Adjustment
^e based on no lateral offset to receptor; parameter has strong decreasing effect with an offset distance
^f effect is only strong if substance biodegrades in the subsurface

Appendix C Tier 2 Modifications

C.1 Assumptions and Parameters

The assumptions and model parameters applied for the calculation of the Tier 1 guidelines form the starting point for any Tier 2 Guideline Adjustments. However, at Tier 2 it may be possible to exclude certain pathways, as discussed in Part B, Section 6 or to adjust the values of certain stable, readily measured parameters to reflect site-specific conditions. Model parameters which can be adjusted at Tier 2 include:

1. source length;
2. source width;
3. depth to contamination;
4. thickness of contamination;
5. depth to groundwater;
6. distance to surface water;
7. hydraulic gradient;
8. saturated hydraulic conductivity;
9. soil organic carbon content;
10. soil dry bulk density;
11. soil moisture content; and,
12. soil vapour permeability.

Details on the data requirements for adjusting these parameters are provided in Appendix C, Section C.8.

C.2 Ranges of Allowable Parameter Adjustment

Model parameters used for Tier 2 Guideline Adjustment generally have limited ranges over which they can vary. Ranges considered to be appropriate, for most Alberta sites, are summarized in Table C-1.

In some cases the ranges are approximate and reflect the range of values that are typically encountered at sites in Alberta. However, for some parameters the ranges are limited by physical constraints or by model assumptions or simplifications that limit the utility of the model outside the typical range. For instance, high moisture contents or large source areas tend to invalidate some of the simplifying assumptions used in the model development and therefore require additional considerations. High rates of transport (associated with high permeabilities) tend to invalidate laminar flow assumptions built into all transport models supplied here. Therefore, if parameter values outside the ranges in Table C-1 are measured at a site, strong supporting data is necessary to demonstrate that the model prediction is appropriate, particularly if it leads to increased Tier 2 remediation guidelines. For variable parameters, long term monitoring is necessary to justify any Tier 2 closure. Where the measured value is outside the range, it is possible to use Tier 2 Guideline Adjustment with a parameter input at the limit of the range.

C.3 Inter-dependence of Parameters

Many of the model parameters used for Tier 2 are linked to or affected by other parameters, and therefore cannot be adjusted independently. All potentially related parameters should be measured together.

Specific sets of linked parameters relevant at Tier 2 include:

1. Soil bulk density, moisture content, total porosity, air-filled porosity and water-filled porosity. The soil bulk density and moisture content are normally used to calculate the other values in this set of parameters. As noted below in Section C.7, moisture content measurements must conservatively reflect seasonal and spatial variations. In most instances for the vapour inhalation pathway, it is more advisable to use the default moisture content rather than measuring the value due to the difficulty in determining long term variability in moisture content. If bulk density or total porosity are altered at Tier 2, then the default moisture content must be adjusted to reflect the ratio of air/water filled pore space in the default case. In all instances, the moisture content must never be set greater than 80% of the effective porosity due to the limitations of the vapor transport model.
2. Source dimensions (source length, source width, depth to contamination, thickness of contamination and depth to groundwater). The source dimension parameters can normally be readily determined from a combination of analytical results and survey data at delineated sites. While depth to groundwater is not a source dimension *per se*, it is used in conjunction with the depth to contamination and thickness of contamination to determine any vertical separation between the contamination and the saturated zone. Values must always be conservative estimates of dimensions. For instance, minimum separation distances between contaminant zone and groundwater, maximum thickness of contamination, maximum source length, width etc. must always be used as model inputs.
3. Hydraulic conductivity and hydraulic gradient. These parameters are often correlated. For sites in similar groundwater flow regimes, it is often observed that a higher conductivity results in a lower hydraulic gradient. Therefore, if one parameter is measured the other should be as well.

The linked parameters are summarized by pathway in Table C-2. Further details on the measurement of these parameters are provided in Section C.8.

Adjusting building parameters would normally imply future land use restrictions and therefore these parameters cannot be adjusted at Tier 2. The exception to this is if adjusting building parameters would result in less conservative guidelines than Tier 1. See Section C.8 for details.

C.4 Petroleum Hydrocarbon Fractions

The calculation for Petroleum Hydrocarbon Fractions is unique and must be taken into account for Tier 2 Guideline Modification.

Petroleum hydrocarbons are a complex mixture of substances. To facilitate the calculation of risk-based soil and groundwater remediation guidelines, each fraction has been divided into several sub-fractions on the basis of chemical structure (aliphatic vs. aromatic) and carbon chain length.

Soil or groundwater remediation guidelines for each PHC fraction were developed by combining guidelines for individual sub-fractions according to the equation below:

$$SGRG (mg / kg - bw / day) = \frac{1}{\sum_i \frac{F_i}{SGRG_i}}$$

Where: SGRG = soil (mg/kg) or groundwater (mg/L) remediation guideline;
 F_i = the assumed proportion of the fraction in soil or groundwater made up of sub-fraction i (dimensionless) and,
 $SGRG_i$ = soil (mg/kg) or groundwater (mg/L) remediation guideline for sub-fraction " i " (mg/kg). For soil, maximum concentration set at 1×10^6 mg/kg.

The assumed proportion of each sub-fraction differs for soil and groundwater, since each sub-fraction partitions differently between soil and groundwater. Assumed sub-fraction distributions for soil and groundwater are provided in Table A-10. The assumed sub-fraction distributions in soil are adopted directly from CCME (2008a). The assumed sub-fraction distributions in groundwater are calculated from the soil values by making standard equilibrium partitioning assumptions and using the following equations:

$$G_i = F_{i(\text{soil})} \frac{\rho_b}{\theta_w + (K_{oc} \times f_{oc} \times \rho_b) + (H' \times \theta_a)}$$

and

$$F_{i(\text{groundwater})} = \frac{G_i}{\sum_i G_i}$$

Where:

G_i	=	proportion of sub-fraction i in groundwater (before normalization; dimensionless);
$F_{i(\text{soil})}$	=	proportion of sub-fraction i in soil (Table A-10; dimensionless);
$F_{i(\text{groundwater})}$	=	proportion of sub-fraction i in groundwater (normalized; Table A-10; dimensionless);
ρ_b	=	dry soil bulk density (g/cm ³);
θ_w	=	moisture-filled porosity (dimensionless);
K_{oc}	=	organic carbon partition coefficient (L/kg);
f_{oc}	=	fraction of organic carbon (g/g);
H'	=	dimensionless Henry's Law Constant (dimensionless); and,
θ_a	=	vapour-filled porosity (dimensionless).

When using a Tier 2 Guideline Modification approach, attention must be maintained to duplicating the procedure on which the Tier 1 values were obtained. In this guideline values are calculated for each subfraction "i" and then the soil or water quality remediation guideline is calculated based on the summation formula above.

C.5 Models, Equations and Protocols for Use in Tier 2 Guideline Adjustment

C.5.1 Human Exposure Pathways

For threshold contaminants, Alberta Tier 1 guidelines are calculated using the toddler and adult models since these are typically found to be sufficient for Tier 1 guidelines. This will typically be sufficient for simple Tier 2 pathway exclusion or guideline adjustment options. However, the Tier 2 SSRA option requires the proponent to revisit all life stages and to reinvestigate sensitive stages (e.g. pregnant or breastfeeding mothers) to ensure protection of these life stages as well.

For further information on the Tier 2 SSRA option, See the Alberta SSRA Guide (GOA, 2022b).

C.5.1.1 Direct Contact

The direct contact pathway cannot be adjusted at Tier 2 except in the case of evaluating a more conservative exposure scenario than the Tier 1 default. The model used to calculate the soil remediation guideline protective of the human direct soil contact (soil ingestion, dermal contact, and particulate inhalation) exposure pathway for the chemicals of potential concern is taken from CCME (2006a). Based on guidance in CCME (2006a) exposure via particulate inhalation was not considered for volatile compounds (IR_s was set to 0 kg/day for volatile chemicals in the equations below). Parameter values were discussed previously and default parameter values are summarized in Tables A-1 to A-9. Separate calculations are made for threshold and non-threshold chemicals.

In some instances, the mechanism of toxicity may be different for the different exposure routes. In these instances, separate guidelines may be calculated based on specific exposure pathways for the gut, skin and particulate inhalation. This option is only available where separate values have been noted in the Tier 1 table for different exposure routes.

Soil guidelines must be protective of both long-term human exposures and potential risks associated with subchronic and acute exposures to high concentrations of a contaminant in soil.

Young children who ingest large amounts of soil (*pica* children) often represent a worst-case scenario for acute exposures. Potential for acute exposure may be assessed using the same procedure but will require re-evaluation of the tolerable intake, based on a short-term exposure event and the exposure rates based on a maximum event.

Threshold Substances

$$SRG_{HDC} = \frac{(TDI - EDI) \times SAF \times BW}{[(AF_G \times SIR) + (AF_L \times IR_S \times ET_2) + (AF_S \times SR)] \times ET_1} + [BSC]$$

Where: SRG_{HDC} = human health-based soil remediation guideline for direct contact (mg/kg);
 TDI = tolerable daily intake (mg/kg bw per day);
 EDI = estimated daily intake (mg/kg bw per day);
 SAF = soil allocation factor (dimensionless);
 BW = adult or toddler body weight (kg);
 AF_G = absorption factor for gut (dimensionless);
 AF_L = absorption factor for lung (dimensionless);
 AF_S = absorption factor for skin (dimensionless);
 SIR = adult or toddler soil ingestion rate (kg/day);
 IR_S = inhalation of particulate matter re-suspended from soil (kg/day);
 SR = adult or toddler soil dermal contact rate (kg/day);
 ET_1 = exposure term 1 (dimensionless) (days/week ÷ 7 x weeks/year ÷ 52);
 ET_2 = exposure term 2 (dimensionless) (hours/day ÷ 24); and,
 BSC = background soil concentration (mg/kg).

Non-Threshold Substances

$$SRG_{HDC} = \frac{(RsD) \times BW}{[(AF_G \times SIR) + (AF_L \times IR_S \times ET_2) + (AF_S \times SR)] \times ET_1} + [BSC]$$

Where: SRG_{HDC} = preliminary human health-based soil remediation guideline (mg/kg);
 RsD = risk-specific dose (mg/kg bw per day);
 BW = adult body weight (kg);
 AF_G = absorption factor for gut (dimensionless);
 AF_L = absorption factor for lung (dimensionless);
 AF_S = absorption factor for skin (dimensionless);
 SIR = adult soil ingestion rate (kg/day);
 IR_S = inhalation of particulate matter re-suspended from soil (kg/day);
 SR = adult soil dermal contact rate (kg/day);
 ET_1 = exposure term 1 (dimensionless) (days/week ÷ 7 x weeks/year ÷ 52);
 ET_2 = exposure term 2 (dimensionless) (hours/day ÷ 24); and,
 BSC = background soil concentration (mg/kg).

Note that, in contrast to the CCME (2006a) protocol, an exposure term is permitted for commercial and industrial land use for non-threshold substances. Alberta exposure terms are captured in Tier 1 defaults.

Where a detailed site-specific risk assessment is required and where the potential for exposure through inhalation or ingestion of particulates has the potential to become a critical exposure route for the contaminant of concern, it will be necessary to re-evaluate the default IR and SIR terms to ensure that they are protective for the potential exposure from contaminated soil suspended in air and exposure through contact with indoor dust for all age groups. Where not, it will be necessary to adjust the model accordingly to account for the increased exposure to the critical individuals. For less detailed Tier 1 and Tier 2 model changes, this analysis is not necessary.

The soil dermal contact rate (SR) is the mass of contaminated soil that is assumed to contact the skin each day. This parameter is calculated as follows (CCME, 2006a):

$$SR = \{(SA_H \times DL_H) + (SA_O \times DL_O)\} \times EF$$

Where: SR = soil dermal contact rate (kg/day);
 SA_H = exposed surface area of hands (m²);
 DL_H = dermal loading of soil to hands (kg/m² per event);
 SA_O = area of exposed body surfaces other than hands (m²);
 DL_O = dermal loading of soil to other surfaces (kg/m² per event); and,
 EF = exposure frequency (events/day).

The soil dermal contact rate is calculated separately for toddlers and adults using the parameters in Table A-1.

C.5.1.2 Vapour Inhalation

Soil and groundwater guidelines protective of the indoor infiltration and inhalation pathway were calculated using the equations from the CCME (2006a) protocol without change for soil and adapted as appropriate for groundwater.

Consistent with the approach taken in CCME (2008a), an adjustment factor of 10 is applied in the equations below for petroleum hydrocarbons (including petroleum hydrocarbon fractions, benzene, toluene, ethylbenzene and xylenes), to account for empirical evidence demonstrating that measured indoor air concentrations are typically lower by at least an order of magnitude than concentrations predicted from the models below. The adjustment factor takes the value of 1 for all other chemicals, reflecting the lack of any empirical data to support such a factor for these chemicals. Parameter values were discussed in Section C.2, and default parameter values are summarized in Tables A-1 to A-9. Separate calculations are made for threshold and non-threshold chemicals.

Soil Guidelines for Threshold Substances

$$SRG_I = \frac{(TC - C_a) \times [\theta_w + (K_{oc} \times f_{oc} \times \rho_b) + (H' \times \theta_a)] \times SAF \times DF_i \times 10^3 \times AF}{H' \times \rho_b \times ET \times 10^6} + BSC$$

Where: SQG_I = soil remediation guideline for indoor infiltration (mg/kg);
 TC = tolerable concentration (mg/m³);
 C_a = background air concentration (mg/m³);
 θ_w = moisture-filled porosity (dimensionless) for contaminated soil;
 K_{oc} = organic carbon partition coefficient (L/kg);
 f_{oc} = fraction of organic carbon (g/g) for contaminated soil;
 ρ_b = dry soil bulk density (g/cm³) for contaminated soil;
 H' = dimensionless Henry's Law Constant (dimensionless);
 θ_a = vapour-filled porosity (dimensionless) for contaminated soil;
 SAF = soil allocation factor (dimensionless);
 DF_i = dilution factor from soil gas to indoor air (calculated below);
 10³ = conversion factor from kg to g;
 AF = adjustment factor (10, hydrocarbons; 1, all other chemicals);
 ET = exposure term (dimensionless);

10⁶ = conversion factor from m³ to cm³; and,
 BSC = background soil concentration (mg/kg).

Soil Guidelines for Non-Threshold Substances

$$SQG_I = \frac{RsC \times [\theta_w + (K_{oc} \times f_{oc} \times \rho_b) + (H' \times \theta_a)] \times DF_i \times 10^3 \times AF}{H' \times \rho_b \times ET \times 10^6} + BSC$$

Where: SQG_I = soil quality guideline for indoor infiltration (mg/kg);
 RsC = risk-specific concentration (mg/m³);
 C_a = background air concentration (mg/m³);
 θ_w = moisture-filled porosity (dimensionless) for contaminated soil;
 K_{oc} = organic carbon partition coefficient (L/kg);
 f_{oc} = fraction of organic carbon (g/g) for contaminated soil;
 ρ_b = dry soil bulk density (g/cm³) for contaminated soil;
 H' = dimensionless Henry's Law Constant (dimensionless);
 θ_a = vapour-filled porosity (dimensionless) for contaminated soil;
 DF_i = dilution factor from soil gas to indoor air (calculated below);
 10³ = conversion factor from kg to g;
 AF = adjustment factor (10, hydrocarbons; 1, all other chemicals);
 ET = exposure term (dimensionless);
 10⁶ = conversion factor from m³ to cm³; and,
 BSC = background soil concentration (mg/kg).

Note that in contrast to the CCME (2006a) protocol, an exposure term of 0.2747 is used for commercial and industrial land use for non-threshold substances. This corresponds to an exposure term of 10 hours/day, 5 days/week and 48 weeks/year, consistent with the commercial and industrial exposure term for threshold substances.

Groundwater Guidelines for Threshold Substances

$$GWRG_I = \frac{(TC - C_a) \times SAF \times DF_i \times AF}{H' \times ET \times 10^3}$$

Where: GWRG_I = groundwater remediation guideline for indoor infiltration (mg/L);
 TC = tolerable concentration (mg/m³);
 C_a = background air concentration (mg/m³);
 SAF = soil allocation factor (dimensionless);
 DF_i = dilution factor from soil gas to indoor air (calculated below);
 AF = adjustment factor (10, hydrocarbons; 1, all other chemicals);
 H' = dimensionless Henry's Law Constant (dimensionless);
 ET = exposure term (dimensionless); and,
 10³ = conversion factor from m³ to L.

Groundwater Guidelines for Non-Threshold Substances

$$GWRG_I = \frac{RsC \times DF_i \times AF}{H' \times ET \times 10^3}$$

Where: GWRG_I = groundwater remediation guideline for indoor infiltration (mg/L);
 RsC = risk-specific concentration (mg/m³);
 DF_i = dilution factor from soil gas to indoor air (calculated below);

- AF = adjustment factor (10, hydrocarbons; 1, all other chemicals);
 H' = dimensionless Henry's Law Constant (dimensionless);
 ET = exposure term (dimensionless); and,
 10³ = conversion factor from m³ to L.

Note that in contrast to the CCME (2006a) protocol, an exposure term of 0.2747 is used for commercial and industrial land use for non-threshold substances. This corresponds to an exposure term of 10 hours/day, 5 days/week and 48 weeks/year, consistent with the commercial and industrial exposure term for threshold substances.

Dilution Factor Calculation

The dilution factor (DF_i) is calculated as follows:

$$DF_i = \frac{1}{\alpha}$$

- Where: DF_i = dilution factor from soil gas concentration to indoor air concentration (unitless); and,
 α = attenuation coefficient (unitless; see derivation below).

$$\alpha = \frac{\left(\frac{D_T^{eff} A_B}{Q_B L_T} \right) \exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}} \right)}{\exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}} \right) + \left(\frac{D_T^{eff} A_B}{Q_B L_T} \right) + \left(\frac{D_T^{eff} A_B}{Q_{soil} L_T} \right) \left[\exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}} \right) - 1 \right]}$$

- Where: α = attenuation coefficient (dimensionless);
 D_T^{eff} = effective porous media diffusion coefficient (cm²/s; calculated below);
 A_B = building area (cm²);
 Q_B = building ventilation rate (cm³/s; calculated below);
 L_T = distance from contaminant source to foundation (cm);
 Q_{soil} = volumetric flow rate of soil gas into the building (cm³/s; calculated below);
 L_{crack} = thickness of the foundation (cm);
 D_{crack} = effective vapour diffusion coefficient through the crack (cm²/s; calculated below); and,
 A_{crack} = area of cracks through which contaminant vapours enter the building (cm²).

Calculation of D_T^{eff}:

$$D_T^{eff} \approx D_a \times \left(\frac{\theta_a^{10/3}}{\theta_t^2} \right)$$

- Where: D_T^{eff} = overall effective porous media diffusion coefficient based on vapour-phase concentrations for the region between the source and foundation (cm²/s);
 D_a = diffusion coefficient in air (cm²/s);
 θ_a = soil vapour-filled porosity (dimensionless); and,
 θ_t = soil total porosity (dimensionless).

Note that this equation assumes that the dominant form of diffusion is through air and therefore cannot be applied to scenarios where diffusion in water may become a dominant form of the transport equation. Therefore, moisture content must always be set to an unsaturated condition in order to apply this equation. It is up to the proponent to

ensure that the moisture content is appropriate to the equation used. Further guidance may be obtained from Johnson (2002).

For Tier 1 and Tier 2 Guideline Adjustments where more than 1 stratum exists, the calculation of D_{τ}^{eff} must be based on the most conservative stratum in the zone of contaminant migration (e.g., the stratum with the highest diffusion coefficient must be used). An exception is allowed for sites where a surficial fine grained deposit exists over a coarse grained deposit. The fine grained layer can be applied to the calculation of D_{τ}^{eff} under the following conditions:

1. Sufficient borehole information is provided to support the presence of a continuous fine grained layer over the entire site,
2. Sufficient borehole information is provided to support estimation of the minimum thickness of the fine grained layer, and
3. The minimum thickness of the fine grained layer is at least 1 m below the depth of typical excavations at the site in the event of construction and at least 1 m below the maximum depth of basements or potential basements at the site.

Where this exception is applied, the depth to the contaminant layer or the groundwater in the model must be set to the minimum depth of the base of the fine grained layer.

For more detailed site-specific risk assessments involving soil vapour measurements, the CCME Vapour Protocol (CCME, 2014), including default parameters noted therein, will need to be applied for the calculation of the appropriate soil vapour guideline. Further information on the SSRA option can be found in the Alberta SSRA Guide (GOA, 2022b).

Calculation of D_{crack} :

D_{crack} is calculated in exactly the same way as D_{τ}^{eff} , with the exception that the assumption is made that the soil material in the cracks is dry (CCME, 2006a), and accordingly, the soil air filled porosity is the same as the soil total porosity, and the equation becomes:

$$D_{\text{crack}} \approx D_a \times \left(\frac{\theta_t^{10/3}}{\theta_t^2} \right)$$

Where: D_{crack} = effective porous media diffusion coefficient in floor cracks (cm^2/s);
 D_a = diffusion coefficient in air (cm^2/s);
 θ_t = total porosity for underlying soil (dimensionless).

In this equation, it is always assumed that the soil properties are based on the properties of the soil surrounding the building foundation.

Calculation of Q_B :

$$Q_B = \frac{L_B W_B H_B ACH}{3,600}$$

Where: Q_B = building ventilation rate (cm^3/s);
 L_B = building length (cm);
 W_B = building width (cm);
 H_B = building height (cm³);
ACH = air exchanges per hour (h^{-1}); and,

3,600 = conversion factor from hours to seconds.

Calculation of Q_{soil} :

$$Q_{soil} = \frac{2\pi\Delta P k_v X_{crack}}{\mu \ln \left[\frac{2Z_{crack}}{r_{crack}} \right]}$$

Where: Q_{soil} = volumetric flow rate of soil gas into the building (cm^3/s);
 ΔP = pressure differential ($\text{g}/\text{cm}\cdot\text{s}^2$);
 k_v = soil vapour permeability to vapour flow (cm^2) for soil adjacent to building foundation;
 X_{crack} = length of idealized cylinder (cm);
 μ = vapour viscosity ($0.000173 \text{ g}/\text{cm}\cdot\text{s}$; CCME, 2006a);
 Z_{crack} = distance below grade to idealized cylinder (cm); and,
 r_{crack} = radius of idealized cylinder (cm; calculated as A_{crack}/X_{crack}).

C.5.1.3 Ingestion of Produce, Meat and Milk

At this time, the guidelines based on the ingestion of produce, meat and milk cannot be modified at Tier 2. For site-specific risk assessments, it is necessary to evaluate the potential risk for this pathway. Further details on the evaluation of this pathway can be found in CCME (2006a). Further details on SSRA option can be found in the Alberta SSRA Guide (GOA, 2022b).

C.5.2 Ecological Exposure Pathways

C.5.2.1 Direct Soil Contact

Soil guidelines based on direct contact by ecological receptors cannot be modified via Tier 2 Guideline Adjustment. Direct ecological toxicity testing for Tier 2 Site Specific Risk Assessment is available for specific compounds (e.g. petroleum hydrocarbons, benzene, toluene, ethylbenzene, xylenes) where toxicity testing protocols are clearly defined and can be replicated in site-specific instances. Alberta Environment and Parks should be consulted prior to site-specific modifications of this pathway.

The groundwater remediation guidelines for the direct ecological soil contact pathway for non-polar organic compounds are based on partitioning of the substance from soil to water described as follows:

Non-polar organic compounds

$$GWRG_{DC} = SRG_{DC} \frac{\rho_b}{\theta_w + (K_{oc} \times f_{oc} \times \rho_b) + (H' \times \theta_a)}$$

Where: $GWRG_{DC}$ = groundwater remediation guideline protective of direct contact with plants and soil invertebrates in areas of shallow groundwater (mg/L);
 SRG_{DC} = soil remediation guideline protective of direct contact with plants and soil invertebrates (mg/kg);
 ρ_b = dry soil bulk density (g/cm^3);
 θ_w = moisture-filled porosity (dimensionless);
 K_{oc} = organic carbon partition coefficient (L/kg);
 f_{oc} = fraction of organic carbon (g/g);
 H' = dimensionless Henry's Law Constant (dimensionless); and,
 θ_a = vapour-filled porosity (dimensionless).

C.5.2.2 Soil and Food Ingestion

Soil guidelines based on soil and food ingestion by livestock and wildlife cannot be modified at Tier 2. Where site-specific risk assessments are conducted, it may be necessary to re-evaluate this pathway to ensure protection of sensitive receptors.

C.5.3 Groundwater Pathways

C.5.3.1 Soil Remediation Guidelines

Soil remediation guidelines for groundwater pathways were calculated using the model and equations from the CCME (2006a) protocol. Soil remediation guidelines for the protection of groundwater are not calculated for inorganic substances due to the uncertainties associated with the partitioning of metals between the adsorbed and dissolved phase. Inorganic substances must be assessed through site-specific groundwater sampling where these pathways are applicable.

Assumptions implicit in the model include the following:

- the soil is physically and chemically homogeneous;
- moisture content is uniform throughout the unsaturated zone;
- infiltration rate is uniform throughout the unsaturated zone;
- depletion of the contaminant source is not considered (*i.e.*, infinite source mass);
- flow in the unsaturated zone is assumed to be one dimensional and downward only (vertical recharge) with dispersion, sorption-desorption, and biological degradation;
- contaminant is not present as an immiscible phase product;
- maximum possible concentration in the leachate is equivalent to the solubility limit of the chemical in water under the defined site conditions;
- groundwater aquifer is unconfined;
- groundwater flow is uniform and steady;
- co-solubility and oxidation/reduction effects are not considered;
- attenuation of the contaminant in the saturated zone is assumed to be one-dimensional with respect to sorption-desorption, dispersion, and biological degradation;
- dispersion in groundwater is assumed to occur in the longitudinal and transverse directions only and diffusion is not considered;
- mixing of the leachate with the groundwater is assumed to occur through mixing of leachate and groundwater mass fluxes; and
- dilution of the plume by groundwater recharge down-gradient of the source is not included.

The soil remediation guideline protective of groundwater uses is calculated in the same way for all five groundwater uses. using the corresponding water quality guidelines as the starting point for each, with two exceptions. The first exception is that the lateral offset between the point at which the contaminated soil is measured and the surface water body (parameter "x" in the dilution factor 4 equation below) is assumed to be 10 m for aquatic life and wildlife watering, and zero for the other water uses. Therefore, dilution factor 4 is only active for aquatic life and wildlife watering and cannot be applied for other pathways. The second exception is that in the calculation of dilution factor 3 for the potable groundwater pathway only, the average thickness of the mixing zone (Z_d) takes the fixed value of 2 m, reflecting the likely minimum screen length for a viable drinking water well. It should be noted that this second point reflects Alberta Environment and Parks policy and is not consistent with CCME (2006a).

The model considers four processes:

1. partitioning of the substance from soil to pore water (leachate);
2. transport of the leachate from the base of contamination to the groundwater table;
3. mixing of the leachate with groundwater; and,
4. transport of the substance in groundwater down-gradient to a discharge point.

For each of these four processes, a dilution factor was calculated (DF1 through DF4, respectively). DF1 has units of (mg/kg)/(mg/L) or L/kg. The other three dilution factors are dimensionless [units of (mg/L)/(mg/L)]. The overall dilution factor is used to calculate the soil concentration that is protective of groundwater using the following equations:

$$SRG_{GR} = SWQG_{FL} \times DF$$

$$DF = DF1 \times DF2 \times DF3 \times DF4$$

Where: SRG_{GR} = soil remediation guideline protective of groundwater pathways (mg/kg);
 $SWQG_{FL}$ = corresponding surface water quality guideline (drinking water, aquatic life, livestock or wildlife watering, or irrigation) (mg/L);
DF = overall dilution factor (L/kg);
DF1 = dilution factor for process 1 (L/kg);
DF2 = dilution factor for process 2 (L/L);
DF3 = dilution factor for process 3 (L/L); and,
DF4 = dilution factor for process 4 (L/L).

Dilution Factor 1

Dilution factor 1 (DF1) is the ratio of the concentration of a contaminant in soil to the concentration in leachate that is in contact with the soil. This “dilution factor” represents the three phase partitioning between contaminant sorbed to soil, contaminant dissolved in pore water (*i.e.*, as leachate), and contaminant present as soil vapour. DF1 is calculated using the following equation:

$$DF1 = K_{oc} \times f_{oc} + \frac{(\theta_w + H' \times \theta_a)}{\rho_b}$$

Where: DF1 = dilution factor 1 (L/kg);
 K_{oc} = organic carbon-water partition coefficient (L/kg);
 f_{oc} = fraction organic carbon (g/g) of the contaminated soil;
 θ_w = water filled porosity (dimensionless) of the contaminated soil;
 H' = dimensionless Henry’s Law constant (dimensionless);
 θ_a = air filled porosity (dimensionless) of the contaminated soil; and,
 ρ_b = dry soil bulk density (g/cm³) of the contaminated soil.

Dilution Factor 2

Dilution factor 2 (DF2) is the ratio of the concentration of a contaminant in leachate that is in contact with the soil, to the concentration in pore water just above the groundwater table. DF2 takes the value 1.00 (*i.e.*, no dilution) for generic guidelines because it is assumed at Tier 1 that the contaminated soil extends down to the water table. However, at Tier 2 a calculated value can be used for DF2 if the contaminated soil is not in contact with the groundwater:

$$DF2 = \frac{1}{\exp\left[\frac{b}{2\hat{\alpha}_u} - \frac{b}{2\hat{\alpha}_u} \left(1 + \frac{4\hat{\alpha}_u L_{US}}{v_u}\right)^{1/2}\right]}$$

$$v_u = \frac{I}{\theta_w R_u}; \quad R_u = 1 + \frac{\rho_b}{\theta_w} K_{oc} f_{oc}$$

- Where: DF2 = dilution factor 2 (dimensionless)
 b = thickness of unsaturated zone below the source (m) = d – Z
 d = depth from surface to groundwater surface (m)
 Z = depth from surface to bottom of contaminated soil (m)
 $\hat{\alpha}_u$ = dispersivity in the unsaturated zone (m) = 0.1b
 L_{US} = decay constant for chemical (y^{-1}) in unsaturated zone:

$$L_{US} = \frac{0.693}{t_{1/2US}} \left(e^{-0.07d} \right)$$

- $t_{1/2US}$ = chemical half-life in unsaturated zone (years)
 v_u = average linear leachate velocity (m/y)
 I = infiltration rate (m/y)
 θ_w = water-filled porosity (unitless) in unsaturated zone;
 R_u = retardation factor in unsaturated zone (unitless)
 ρ_b = soil bulk density in unsaturated zone (g/cm^3)
 K_{oc} = organic carbon-water partition coefficient (L/kg); and,
 f_{oc} = fraction organic carbon (g/g) in unsaturated zone;

Dilution Factor 3

Dilution factor 3 (DF3) is the ratio of the concentration of a chemical in pore water just above the groundwater table, to the concentration in groundwater beneath the source. This dilution factor reflects a decrease in concentration as leachate mixes with uncontaminated groundwater. DF3 is a function of groundwater velocity, infiltration rate, source length, and mixing zone thickness. The mixing zone thickness is calculated as being due to two processes: i) mixing due to dispersion, and ii) mixing due to infiltration rate. The equations used are as follows:

$$DF3 = 1 + \frac{Z_d \times V}{I \times X}$$

$$Z_d = r + s$$

$$r = 0.01 \times X$$

$$s = d_a \left\{ 1 - \exp \left(\frac{-2.178 \times X \times I}{V \times d_a} \right) \right\}$$

$$V = K \times i$$

- Where: DF3 = dilution factor 3 (dimensionless);
 Z_d = average thickness of mixing zone (m);
 V = Darcy velocity in groundwater (m/year);
 I = infiltration rate (m/year);
 X = length of contaminated soil parallel to groundwater flow (m);
 r = mixing depth due to dispersion (m);
 s = mixing depth due to infiltration rate (m);
 d_a = unconfined aquifer thickness (m);
 K = aquifer hydraulic conductivity (m/year); and,
 i = lateral hydraulic gradient in aquifer (dimensionless).

Note that the parameter Z_d takes the fixed value of 2 m for the drinking water pathway, but is calculated as above for all other pathways.

Dilution Factor 4

Dilution factor 4 (DF4) accounts for the processes of dispersion and biodegradation as groundwater travels downgradient from beneath the source of contamination, and is the ratio of the concentration of a chemical in groundwater beneath the source, to the concentration in groundwater at a distance (10 m for Tier 1 for aquatic life and wildlife watering) downgradient of the source. For distances less than 10 m, a value of 1 should be used for DF4.

$$DF4 = \frac{4}{\exp(A) \times \operatorname{erfc}(B) \times [\operatorname{erf}(C) - \operatorname{erf}(D)]}$$

$$A = \frac{x}{2D_x} \left\{ 1 - \left(1 + \frac{4L_s D_x}{v} \right)^{1/2} \right\}$$

$$B = \frac{x - vt \left(1 + \frac{4L_s D_x}{v} \right)^{1/2}}{2(D_x vt)^{1/2}}$$

$$C = \frac{y + Y/2}{2(D_y x)^{1/2}}$$

$$D = \frac{y - Y/2}{2(D_y x)^{1/2}}$$

$$L_s = \frac{0.6931}{t_{1/2s}} (e^{-0.07d})$$

$$v = \frac{V}{\theta_t R_s}$$

$$R_s = 1 + \frac{\rho_b K_{oc} f_{oc}}{\theta_t}$$

$$D_x = 0.1x$$

$$D_y = 0.01x$$

Where:

DF4	=	dilution factor 4 (dimensionless);
erf	=	the error function;
A	=	dimensionless group A (dimensionless);
C	=	dimensionless group C (dimensionless);
D	=	dimensionless group D (dimensionless);
x	=	lateral distance between source and receptor (m);
D _x	=	dispersivity in the direction of groundwater flow (m);
L _s	=	decay constant (1/year);
v	=	velocity of the contaminant (m/year);
t	=	transport time (500 yr);
y	=	distance to receptor perpendicular to groundwater flow (m);
Y	=	source width perpendicular to groundwater flow (m);
D _y	=	dispersivity perpendicular to the direction of groundwater flow (m);
t _{1/2s}	=	decay half-life of contaminant in saturated zone of aquifer (years);
d	=	water table depth (m);
V	=	Darcy velocity in groundwater (m/year);
θ _t	=	total soil porosity (dimensionless) in the aquifer;
R _s	=	retardation factor in saturated zone (dimensionless);
ρ _b	=	dry soil bulk density in the aquifer (g/cm ³);
K _{oc}	=	organic carbon partition coefficient (mL/g); and,
f _{oc}	=	fraction organic carbon (g/g) in the aquifer.

Groundwater Remediation Guidelines

It is assumed that a dugout could potentially be constructed at any location on agricultural land and, accordingly, the livestock watering and irrigation water quality guidelines are applicable as groundwater remediation guidelines across all agricultural land. Furthermore, it is assumed that a water well could be constructed anywhere within a Domestic Use Aquifer (DUA) (see Appendix E). Accordingly, the drinking water quality guidelines must be applied as groundwater remediation guidelines within the entire DUA. Therefore any modification of these guidelines is considered Exposure Control.

For aquatic life or wildlife watering, it is assumed that there is a minimum 10 m lateral separation between the point of measurement and the surface water body; this distance can be modified at Tier 2. The groundwater remediation guideline protective of aquatic life and wildlife watering is calculated using the following equations.

$$GWRG_{GR} = SWQG \times DF4$$

Where: $GWRG_{GR}$ = groundwater remediation guideline protective of groundwater pathways (mg/L);
 $SWQG_{FL}$ = corresponding surface water quality guideline (aquatic life, or wildlife watering) (mg/L);
DF4 = dilution factor for process 4 (dimensionless). DF4 is calculated as above.

C.6 Site-Specific Adjustments Not Supported at Tier 2

Several parameters that may have an influence on the fate and exposure models cannot normally be modified at Tier 2:

1. Human receptor characteristics have been selected by Health Canada as representative of the Canadian population based on the best available data and are therefore not adjustable at Tier 2. An exception is made if there is reason to believe that the characteristics of human activity lead to greater exposure than used in the default assumptions. In this instance, a site-specific risk assessment should be employed that incorporates the use of the more sensitive receptor characteristics. For instance, where the consumption of food from the area is greater than for the average population, it is necessary to conduct a Tier 2 adjustment to account for this increased risk.
2. Exposure scenarios have been selected to represent typical land uses. While in some cases it may be acceptable to adjust exposure scenarios while the proponent retains ongoing control of the site this requires administrative controls to ensure the exposure scenario is maintained and therefore requires use of the Exposure Control option. If the exposure scenario at a site is believed to be more conservative than the default for the appropriate land use, it may be possible to use a more conservative land use that captures the appropriate exposure scenario. If this is not possible, a site-specific evaluation is undertaken that will recalculate the guidelines based on the more sensitive exposure scenario.
3. Receptor locations (e.g. lateral offsets to buildings or potable water wells) cannot be adjusted at Tier 2. Use of lateral offsets requires Exposure Control since future receptor locations can change. The exceptions are the distance to a surface water body that is fixed or the distance to a building more sensitive than the default scenario (as discussed below). The presence of large diameter bored wells in low permeability soil can also be considered under a lateral offset. For details, see Part B, Section 6.3, and Appendix E. For Exposure Control scenarios, it is possible to use calculations based on current receptor locations to justify the ongoing administrative or technical controls.
4. Building properties are based on typical construction practices. Since Tier 2 objectives must be protective of future as well as existing buildings, adjustment of building properties is not normally allowed at Tier 2. The exception is if a building more sensitive than that normally assumed is currently present at the site (e.g., a building without a concrete foundation or a building with a very low air exchange rate). In this case, Tier 2 objectives must be calculated separately for both the default building and the current building cases, with the lowest calculated objectives being applied. The calculations for the current building can be performed based on the current location of the building in this case only; the calculations for the default building would be performed based on a hypothetical building placed directly above the contamination.
5. Recharge (infiltration) rate is strongly affected by landscape and soil properties as well as rainfall, and therefore cannot be adjusted at Tier 2. An exception is made in the case of heterogeneous soil stratigraphy when there is a continuous fine-textured soil layer overlying a coarse-textured aquifer. Only in this case can the fine soil recharge rate be applied at a site otherwise classified as having coarse-textured soils. The proponent must demonstrate that the fine soils are continuous above the entire contaminated area and of sufficient thickness to reduce the infiltration rate. A minimum thickness of 1 m is required across the entire site to apply this correction.

C.7 Conditions Where Site-specific Risk Assessments are Required.

Tier 2 procedures presented herein are appropriate for sites that are fundamentally similar to the Tier 1 assumptions and are not applicable for sites that have significantly different properties. In these instances, it is necessary to conduct a site-specific risk assessment at Tier 2 rather than moving to simple Tier 2 model modifications. Specific conditions that will lead to Tier 2 guideline model adjustments not being applicable include:

The Presence of Preferential Flow Paths

Fate and transport models applied for Tiers 1 and 2 are based on transport through porous media (i.e. unconsolidated soils), and are not appropriate for modeling transport through bedrock fractures. For small fractures, it may still be possible to apply Tier 1 or Tier 2 approaches. Site-specific risk assessment is required where flow paths in the fractured bedrock cannot reasonably be expected to behave similarly to those in an aggregated soil medium. When fracture length exceeds approximately 2 cm, flow paths in the fractured bedrock may be different than those in an aggregated soil medium and the use of Darcy equation in describing flow needs to be re-evaluated. Where fracture planes are large enough that the principles of Darcy flow cannot be guaranteed, site specific risk assessment is required. In all cases, health and ecological protection objectives must be maintained.

Other preferential flow paths may be present that mitigate direct application of Tier 2 processes. Where a preferential flow path may exist, it needs to be assessed prior to application of generic transport models. Where the model is not appropriate, a Tier 2 SSRA approach is warranted. For instance, small lenses or utility corridors comprised dominantly of coarse textured materials may act as preferential flow paths, particularly where direct transport from the zone of contamination to the receptor of interest beyond Tier 1 or Tier 2 assumptions occurs.

Source of Contamination Within 30 cm of an Existing Building

The Johnson and Ettinger (1991) model is not considered reliable for contamination very close to the building (Health Canada, 2010). Therefore, for contamination within 30 cm of a hypothetical or existing building foundation, a site-specific risk assessment approach to evaluate volatile organic compound transport into the building should be applied. Alternatively, an attenuation factor of 0.01 (i.e. a dilution factor of 100 from soil gas to indoor air) can be applied at Tier 2 instead of the site specific risk assessment.

Groundwater Flow to Stagnant Water Bodies

Additional consideration is required if groundwater at a site has the potential to discharge to a stagnant water body. A stagnant water body is defined as a water body without significant outflow, and where the main pathway of water loss is via evaporation. Stagnant water bodies will tend to concentrate discharging groundwater contaminants through evaporation. Water bodies with no obvious or known outflow should be considered stagnant. If outflow is suspected via groundwater and no obvious surface outflow is present, a groundwater investigation will be needed to provide confirmation.

In the assessment of whether soil or groundwater contaminants are likely to have an adverse effect on a stagnant surface water body, the concentrations of contaminants in groundwater are less important than the long-term effect on contaminant concentrations in the stagnant water body. Accordingly, when there is the potential for a contaminant in groundwater at a site to discharge to a stagnant surface water body, a SSRA is required for a mass balance assessment of the likely effect on the concentrations of that contaminant in the stagnant water body over the anticipated lifetime of the groundwater discharge in addition to other considerations for the water body. The assessment should take into consideration, in a qualitative sense, the likelihood of other potential future contaminant releases to the stagnant surface water body. Unless the effect on contaminant concentrations in the stagnant surface water body can be shown to be insignificant, remedial action will be required.

Greater Exposure than Considered at Tier 1

In some cases receptors at the site may experience much greater exposure than what is assumed at Tier 1 or Tier 2. In these instances, a more detailed site-specific risk assessment may be required to demonstrate that the appropriate sensitive receptor or land use is protected at the generic levels or the required remediation guidelines will need to be

adjusted accordingly. In some instances, this may be dealt with through a Tier 2 Guideline Adjustment. For instance, where the concern is over food ingestion from the site, it may be possible to account for increased exposure by using the model at Tier 2 and modifying the food ingestion rates.

Sensitive Ecological Habitats

The Tier 1 ecological soil contact values are based on a level of protection deemed to be appropriate for most land uses. However, they may not be sufficiently protective of very sensitive ecological habitats or potential for sensitive land uses. The presence of a sensitive ecological habitat generally warrants a site-specific risk assessment.

C.8 Data Requirements for Tier 2 Modification

Tier 2 modification requires more detailed site data than a typical Tier 1 assessment.

C.8.1 Contaminant Characterization

Detailed contaminant characterization is required at Tier 2, including the extent of contamination. Lateral and vertical delineation of the contamination must be supported by appropriate laboratory analyses. Sites that are not fully delineated (e.g. lateral and vertical extent of contaminated zone is fully delineated and can be mapped) are not eligible for Tier 2 modifications since the assumptions for modifications cannot be supported by site information. In addition, information is needed to support Tier 2 decisions over and above contaminant characterization. Specific information that may be needed for Tier 2 modification includes:

1. **Source length** – For the purpose of the groundwater model only, the source is defined as anything that adds contaminant mass to the groundwater since the model only considers contamination that enters the groundwater pathway. The model requires the total length of the contaminant source in the direction parallel to the primary direction of groundwater flow. If the direction of groundwater flow cannot be reliably determined or is variable, the longest dimension of the source must be used to represent the source length. The source length is determined from soil analytical data, and is used for all groundwater protection pathways. Increased source length reduces the Tier 2 levels. A source length greater than the Tier 1 default (10 m) leads to an automatic requirement for Tier 2 or higher assessment unless the contaminant delineation shows that the volume is less than 300 m³.
2. **Source width** – the total length of the contaminant plume in the direction normal to the primary direction of groundwater flow. If the direction of groundwater flow cannot be reliably determined or is variable, the longest dimension of the plume should be used to represent the source width. The source width is determined from soil analytical data, and is used to calculate the guidelines for the groundwater protection pathways if there is separation between the contamination and the receptor. Source width is generally not a highly sensitive parameter in the groundwater model.
3. **Depth to soil contamination** – the distance from grade to the contamination. The depth to contamination is determined based on soil borehole and analytical data; if it varies across a site, the shallowest depth to contamination should be used. It is used for Tier 2 evaluation of the vapour inhalation pathway, in combination with other parameters. Depth to contamination may also affect the groundwater protection pathways and influence site management strategies.
4. **Thickness of soil contamination** – the distance from the top of the contamination to the bottom of the contamination. The contamination thickness is determined based on soil analytical data. It is used in combination with the depth to soil contamination and depth to groundwater to determine the separation distance (if any) between the contamination and groundwater. Where this depth is used to determine a separation distance between the soil and groundwater, a detailed delineation of the depth of soil contamination and groundwater depth must both be performed in and around the contaminant zone. The depth to soil contamination in combination with the thickness of soil contamination must be set in such a way that it describes the minimum distance between the groundwater and the base of the contaminant zone. The site specific information on contaminant thickness must reliably predict the maximum contaminant thickness. If this cannot be reliably determined, zero separation distance to the groundwater must be assumed.

C.8.2 Physical Site Conditions

Several physical site characteristics are used in the fate and transport models applied at Tier 2, and should therefore be measured when appropriate.

Depth to Groundwater

Depth to groundwater is the distance from grade to the water table. The depth to the water table may vary and there may be more than one aquifer at the site; for most Tier 2 purposes, the seasonal high water table in the shallowest aquifer is the most important. Depth to groundwater is normally measured using appropriately screened monitoring wells which have been given sufficient time to reach equilibrium. While observations from soil borings are often useful to help identify the anticipated water table location, they are not considered reliable enough to specify the depth to groundwater at Tier 2. The depth to groundwater is used for calculating vapour inhalation-based groundwater objectives and for all protection of groundwater exposure pathways. Normally the shallowest depth to groundwater is used in these calculations. However, depth to groundwater at other locations is also used to determine the hydraulic gradient (below).

Information on depth to groundwater must reliably estimate both the mean depth and the variation both spatially and temporally across the site. In modeling, conservative estimates of the parameter in question (e.g. estimates resulting in the most conservative risk-based guidelines) are always required. Where groundwater depth has the potential to vary considerably over time, the highest potential water table must be used in estimating depth to the water table.

Distance to Surface Water

Distance to surface water is the distance between the edge of the contamination and the nearest surface water body. Increased distance to surface water results in increased Tier 2 objectives for the protection of aquatic life and wildlife watering. Any permanent or seasonal water body that may support aquatic life must be considered. For the purpose of the wildlife watering pathway, any permanent or seasonal water body must be considered regardless of potential to support aquatic life.

Distance to surface water must be measured from the minimum distance to a stable or decreasing contaminant zone from the flood risk area of the water body. Where the contaminant zone is within the flood risk area, a separation distance of 0 may be necessary.

Hydraulic Gradient and saturated Hydraulic Conductivity

Hydraulic gradient and hydraulic conductivity cannot be assessed independently; both are required if Tier 2 changes to one parameter are anticipated. The amount of information needed for any Tier 2 alterations is dependent on site characteristics. However, a minimum of 3 monitoring wells is required for simple sites with small plumes and simple (single unit) stratigraphies. In other circumstances, additional monitoring wells are always required. In all instances, monitoring must be sufficient to completely describe water table depth, flow direction and Darcy's velocity and variability in these parameters across the entire area of concern. Model inputs must always assume conservative estimates (e.g. estimates leading to conservative risk based guidelines) rather than mean estimates of the Darcy's velocity for the pathway of interest. Where only the minimum 3 points are available, inputs are always based on the most conservative value of the 3 measurements.

Hydraulic gradient describes the slope of the groundwater surface, based on measured groundwater elevations across the site. The hydraulic gradient must be measured over an area representative of the entire area of interest, capturing all potential exposure pathways, and be relevant to the aquifer of concern. The hydraulic gradient is used with the saturated hydraulic conductivity to determine the groundwater velocity and the velocity of dissolved contaminants. The hydraulic gradient is used for all groundwater protection pathways.

Saturated hydraulic conductivity is a measure of how easily water can flow through the soil, usually measured by performing bail tests or slug tests on a monitoring well, but also sometimes measured in the laboratory on undisturbed soil samples. When laboratory measurements are used, the results must be multiplied by 10 to account for small sample volumes. Hydraulic conductivity is measured for the soil strata through which groundwater is flowing,

especially more permeable strata which may dominate groundwater flow. If measured from a monitoring well, the well must be screened across the stratum of interest.

For anisotropic media, the saturated hydraulic conductivity must appropriately characterize the flow direction of importance. In general, this means that lateral flow within the aquifer will be of most importance except where vertical separation from a DUA is being demonstrated, in which case vertical flow becomes of greater importance. For heterogeneous media, the hydraulic conductivity should be estimated based on the most likely zone that will dominate groundwater flow. In most instances, this means that the medium with the highest conductivity will control groundwater transport and must be used except where this is a small, discontinuous layer.

Soil Organic Carbon Fraction

Soil organic carbon is the fraction of soil by weight comprised of organic carbon (weight of organic carbon/weight of soil). The organic carbon content of the contaminated soil type (for vapour inhalation and groundwater protection pathways) and of any aquifers through which contaminants may migrate (for groundwater protection pathways) is a key parameter for calculating Tier 2 soil objectives. The organic carbon content must not be measured in soils contaminated with high concentrations of organic chemicals, since this may result in a false high reading. Rather, it must be measured in the same soil type at the same depth, but outside the contaminant source area. At least three samples from each soil stratum of interest are normally required, with increasingly more samples being required for large contaminant zones or aquifer flow paths or sites with complex stratigraphy (more than one stratigraphic unit) represented by the contaminant zone.

Organic carbon content must be sufficiently characterized to demonstrate both the mean and the variability in the organic matter present in the stratum of interest and allow for a conservative estimate of organic carbon for the site. Where only three samples are available, the most conservative value (the value resulting the most conservative estimate of the Tier 2 guidelines) is used.

Field sampling of organic carbon must be appropriate to the desired use in the Tier 2 model. For changes to the groundwater model, this means that measurements must characterize the organic carbon content from the contaminant zone to the receptor of interest and allow for a conservative estimate of organic carbon content across the entire area. For use in chemical partitioning from the groundwater to air (for the vapour inhalation pathway), organic carbon fraction must be representative of the contaminant zone and be taken from appropriate vertical and horizontal locations to characterize this layer without interference from the contaminant zone.

The organic carbon fraction is measured in a laboratory. It is essential that organic carbon (as opposed to total carbon or inorganic carbon) is reported.

Partitioning estimates based on models provided in this document assume linear partitioning with relatively uniform organic carbon materials, usually based on K_{oc}/K_{ow} relationships. As such, these estimates are only appropriate for mineral soils and for soils where organic materials are relatively uniformly mixed throughout the deposit. High organic soils may not have the same K_{oc}/K_{ow} relationships.

Where the organic carbon is heterogeneously located throughout the deposit (e.g. in the case of coal flecks in a stratum of interest), application of model changes at Tier 2 based on organic carbon content are not permitted.

In both these instances, although the deposit may afford additional protection not taken into account by the model, it is necessary to proceed to site-specific risk assessment with appropriate monitoring to demonstrate the additional protection offered by the stratum of interest.

Soil Dry Bulk Density

The mass of soil per unit volume, measured from undisturbed soil samples or by geophysical methods. This parameter is related to total soil porosity, and, along with water content, affects the moisture-filled porosity and air-filled porosity. As a result, bulk density has indirect effects on both vapour transport and groundwater transport with higher bulk density resulting in reduced contaminant transport. Bulk density also affects partitioning calculations with higher bulk density leading to higher calculated dissolved-phase and vapour-phase chemical concentrations.

Depending on the distance between the contaminant source and receptors, higher bulk density can lead to either higher or lower Tier 2 objectives. Soil bulk density is relevant for both the soil strata in which contamination resides and all strata through which contaminant transport potentially occurs. In addition, soil bulk density indirectly affects total porosity, air filled porosity and moisture filled porosity. Therefore the measurement will need to be appropriate to the point of interest.

There are 4 locations where soil bulk density measurements may come into play. These locations include:

1. Vapour inhalation: the zone between the contaminant zone and the zone immediately next to the building (as it affects porosity and air filled porosity).
2. Vapour inhalation and groundwater pathways: partitioning immediately at the contaminant zone.
3. Groundwater pathways: the zone between the contaminant and the groundwater table (only applies if a vertical separation distance between the contaminant zone and the groundwater is applied)
4. Groundwater pathways: the zone of transport along the aquifer (only applies to pathways where a horizontal separation distance is allowed).

As some of these inputs have little or no influence on the outcome, it may be advisable to conduct a sensitivity analysis to ensure that measurements are taken from the locations that have potential to influence the model outcome. This analysis should include factors that are influenced by bulk density (e.g. air filled porosity, moisture filled porosity, total porosity). Where the model is relatively insensitive to changes, default inputs can be used rather than conducting direct measurements.

As with other parameters, a minimum of 3 measurements are required in the appropriate zone for simple stratigraphies and small contaminant zones. For more complex sites, additional measurements are required to fully describe the expected range for the site. Conservative inputs must always be used in model calculations. Where only 3 measurements are available, the value resulting in the most conservative outcome must be applied.

For the zone of transport along the vapour inhalation pathway, the measurement of bulk density and porosity must represent the point resulting in the most conservative input along the transport path. In most instances for homogeneous media, this means that measurements will need to be taken near surface (above 0.5 m depth) to represent the typical conservative zone for a slab on grade foundation. However, there are some instances for heterogeneous media where this may require deeper measurements to capture a zone that represents a faster potential rate of contaminant transport than that immediately near the surface.

Soil Moisture Content (Unsaturated Zone)

The mass of water per mass of soil. Soil moisture content may be measured on either a volume per unit volume or mass per unit mass basis. These two calculations lead to very different values that are related through the soil bulk density. It is up to the proponent to ensure that the appropriate units are applied depending on the structure used in the model.

Along with the dry bulk density, moisture content affects the moisture-filled porosity and air-filled porosity. It has similar effects on Tier 2 vapour inhalation objectives as bulk density (i.e. higher water content generally increases Tier 2 objectives if there is a significant distance between the contamination and receptor, but may decrease Tier 2 objectives if there is very little separation). Soil water content is included in the models in three areas:

1. Vapour inhalation and groundwater pathways: partitioning immediately at the contaminant zone.
2. Groundwater pathways: the zone between the contaminant and the groundwater table (only applies if a vertical separation distance between the contaminant zone and the groundwater is applied)
3. Groundwater pathways: the zone of transport along the aquifer (only applies to pathways where a horizontal separation distance is allowed).

Moisture content can be measured in a laboratory by measuring the mass of soil before and after drying. However, since water content may vary both spatially and temporally, sufficient samples to represent all soils of interest would

be required, and enough sampling must be taken to measure seasonal variation of moisture content. In most instances, field-based monitoring equipment that can continuously monitor moisture changes or other similar long term monitoring programs to accurately assess field moisture content are recommended.

Moisture content may be lower beneath buildings, so samples collected outside the footprint of existing buildings may not reflect conditions beneath a building if vapour transport with a depth to contamination greater than the default is being modeled. Additionally, moisture contents measurements in the zone of transport for the vapour inhalation pathway must be made for the most conservative point on the path of transport unless a more detailed site-specific risk assessment with long term monitoring is employed. In most instances, this means that moisture measurements for this pathway must be consistent with the theoretical depth below a slab on grade foundation (e.g. shallower than 50 cm) as this represents the zone of lowest moisture content as well as the zone with highest potential variation (e.g. highest rates of evapotranspiration). It is also noted that data must be sufficiently large to estimate the seasonal variation in moisture content at this depth and apply a conservative estimate of the moisture content.

For most applications, use of moisture contents other than the default for the vapour inhalation pathway are not recommended due to the difficulty in obtaining a defensible data set and demonstrating conservative estimates of near surface values that are significantly different than the default scenario. For deep contaminant zones where the majority of transport is through specific geological deposits that have relatively stable moisture contents (e.g. are well outside the soil profile influenced by evapotranspiration), it is more likely possible to adequately assess the moisture content. However, this requires a site-specific risk assessment, including a more detailed evaluation of the stratigraphy of the site.

Where bulk density and total porosity are modified based on site-specific data the default moisture content may be applied but it must be recalculated to ensure consistency with the ratio of moisture filled porosity to total porosity in the appropriate soil texture category.

Soil Vapour Permeability

Soil vapour permeability is a measure of how easily vapours flow through the soil. This parameter has a strong influence on the vapour inhalation pathway, with a higher soil vapour permeability resulting in lower Tier 2 objectives. Vapour permeability can be measured in the field with pneumatic tests. However results of these tests have been shown to be affected by the distance between monitoring points. Field measurements may be influenced by moisture content and may not represent the potential permeability associated with the building. Therefore, field measurements must account for these variabilities.

Soil vapour permeability can be estimated as a function of hydraulic conductivity, water content and total soil porosity (US EPA, 2003). Vapour permeability should reflect soils close to the building foundation and soils which may be close to the foundations of future buildings. In general, this means that conservative measurements will reflect the near surface permeabilities (e.g. at depths less than 0.5 m) to be reflective of the most permeable layer near a slab-on-grade foundation. However, in some instances where more permeable layers may exist at a depth where there is potential for the building foundation to be located, this location must be measured.

Permeability measurements must be detailed enough to reflect variation across the entire area of interest and must be of sufficient quantity to capture natural variation in field sites. A minimum of 3 measurements are required for small sites with simple stratigraphy. Larger sites or more complex geology will always require more than the minimum number of samples. Where more than one layer exists across the site within the typical foundation depth, the zone with the highest permeability must be used in the Tier 2 estimate.

Conservative estimates of permeability must always be applied to the model. Where only 3 samples are available, the highest permeability measured must always be used as a model input.

Calculated Parameters

The total soil porosity, moisture-filled porosity and air-filled porosity can be calculated from the dry bulk density and water content as follows:

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

$$\theta_w = \frac{\rho_b M_w}{\rho_w}$$

$$\theta_a = n - \theta_w$$

Where: n = total soil porosity (cm³ pore space per cm³ soil)
 θ_w = water-filled porosity (cm³ water per cm³ soil)
 θ_a = air-filled porosity (cm³ air per cm³ soil)
 M_w = soil water content (g water per g dry soil)
 ρ_s = soil particle density = 2.65 g/cm³
 ρ_b = soil dry bulk density (g/cm³)
 ρ_w = density of water = 1 g/cm³

θ_w cannot exceed n . When θ_w is equal to n the soil is saturated with water.

Where the default moisture content is being applied, but changes are being made to the bulk density and total porosity, the above equations can be used to estimate θ_w/θ_a for the default soil texture and this ratio can then be used to calculate a new value for θ_w and θ_a based on the change to bulk density.

TABLE C-1 PRIMARY TIER 2 ADJUSTABLE PARAMETERS AND ILLUSTRATIVE RANGES

Parameter	Default	Illustrative Range
Measured Parameters		
Bulk Density (g/cm ³)	c/g: 1.7 f/g: 1.4	c/g: 1.5 - 1.8 f/g: 1.3 - 1.6
Moisture Content (gravimetric) (M _w /M _s)	c/g: 0.07 f/g: 0.12	c/g: 0.03 - 0.15 f/g: 0.07 - 0.16
Organic Carbon Fraction (g/g)	0.005	c/g: 0.0005 - 0.007 f/g: 0.0005 - 0.03
Soil Vapour Permeability (cm ²)	c/g: 6x10 ⁻⁸ f/g: 10 ⁻⁹	c/g: 10 ⁻⁶ - 10 ⁻⁸ f/g: 10 ⁻⁸ - 10 ⁻¹²
Saturated Hydraulic Conductivity (m/y)	c/g: 320 f/g: 32	c/g: 32 - 3200 f/g: 0.032 - 32
Hydraulic Gradient (unitless)	0.028	0.001 - 0.1
Depth/distance to Contamination (m) ^a	0.3	0 - 10
Thickness of Contamination (m) ^b	3	0.5 - 5
Depth to Groundwater (m) ^c	3	0 - 10
Site Length (m) - parallel to GW flow	10	5 - 30
Site Width (m) - perpendicular to GW flow ^b	10	5 - 30
Distance to nearby surface water (m) ^b	10	0 - 300
Distance to potable water or agricultural water (m)	0	0 - 300
Calculated Parameters		
Effective Porosity	c/g: 0.36 f/g: 0.47	See note d
Water-filled Porosity	c/g: 0.119 f/g: 0.168	See note e
Air-filled Porosity	c/g: 0.241 f/g: 0.302	See note e
Distance from Contamination to Groundwater (m) ^b	0	See note f

c/g – coarse-grained soil

f/g – fine-grained soil

a – distance from the nearest point of the foundation of an occupied building

b – parameter only used in the calculation of leaching to groundwater and transport to nearby surface water bodies

c – depth below grade

d – calculated from bulk density, assuming soil particle density of 2.65 (see C.8.2)

e – derived from bulk density and water content (see C.8.2)

f – calculated from depth to contamination, depth to groundwater, and thickness of contamination

TABLE C-2 LINKED PARAMETER GROUPS

Pathway	Parameter Groups
Vapour Inhalation	<i>Group 1 – Soil Properties^a</i>
	- dry bulk density
	- moisture content
	- total porosity (calculated)
Groundwater Pathways	- air-filled porosity (calculated)
	- water-filled porosity (calculated)
	<i>Group 2 – Building Properties^b</i>
	- building length
	- building width
	- effective building height
	- depth to foundation base
	- foundation slab thickness
	- crack area
	- crack length
- pressure differential	
- air exchange rate	
Groundwater Pathways	<i>Independent Parameters</i>
	- soil organic carbon fraction
	- soil vapour permeability
	- depth to contamination (soil objectives)
	- depth to groundwater (groundwater objectives)
	<i>Group 1 – Soil Properties^a</i>
	- dry bulk density
	- moisture content
	- total porosity (calculated)
	- air-filled porosity (calculated)
- water-filled porosity (calculated)	
Groundwater Pathways	<i>Group 2 – Source Dimensions</i>
	- source length (parallel to groundwater flow)
	- source width (normal to groundwater flow)
	- depth to contamination
	- thickness of contamination
Groundwater Pathways	- depth to groundwater
	<i>Group 3 – Hydrogeological Parameters</i>
	- saturated hydraulic conductivity
Groundwater Pathways	- hydraulic gradient
	<i>Independent Parameters</i>
Groundwater Pathways	- soil organic carbon fraction
	- distance to receptor

^a Dry bulk density and total porosity are measured concurrently from the same sample. Moisture content is more problematic as it must reflect both spatial and temporal variability for the site. In practice, this measurement is difficult to assess and may require use of default parameters except in instances where samples are either from deep stratum that may be associated with consistent moisture contents or where use of more detailed monitoring protocols (e.g. use of moisture probes with long term monitoring) are employed.

^b Adjustment of building properties is not normally permissible at Tier 2, except to evaluate a building more sensitive than the Tier 1 default

Groups of parameters must be adjusted together (i.e. if a site-specific value is used for one parameter, site-specific values must be used for all parameters in the group). Independent parameters can be varied individually based on site-specific data

Appendix D

Point-of-Exposure or Exposure Pathway Measurements

Point-of-exposure or exposure pathway measurements of contaminant concentrations in appropriate media provide a means of increasing the realism and reliability of fate and transport modeling. Examples of such measurements are vapour-phase concentrations in soil gas and dissolved concentrations in groundwater at or near the contaminant source, at the point of compliance, or an intermediate point along the lateral transport pathway.

Although the use of exposure pathway measurements is a site-specific, data-based, technical procedure, the application of these measurements at Tier 2 differs from the use of user-adjustable parameters to calculate site-specific objectives. In the derivation of soil quality or remediation objectives, fate and transport modeling is used to establish a relationship between the concentration in soil at the contaminant source and the exposure concentration experienced by the receptor and, hence, risk. The relationship is used to determine the allowable source concentration or remediation objective corresponding to a target exposure concentration or risk. Adjusting assumptions used in the modeling would result in a change in remediation objective for the same target risk or health protection objective.

While exposure pathway measurements can be used to assist in the calibration of fate and transport models, they would not normally be used to recalculate soil objectives. Instead, they would be used in combination with modeling and long-term monitoring to ensure that existing contaminant concentrations in soil, water or air would not lead to exceedance of the target risk level, or health protection objectives. Depending on where point of exposure measurements are made, this involves a varying level of modeling either to back calculate appropriate concentrations at the point of measurement or to forward calculate time-dependent changes in concentration from the contaminant zone. Depending on the nature of the measurement, modeling of changes in the risk estimate with time will be a necessary component, particularly where the scenario is not in a steady state condition.

Point-of-exposure measurements are always conducted as part of more detailed site-specific risk assessment. Long term monitoring is always required for these approaches to verify the conservative nature of model predictions. In addition, these approaches may require more detailed assessment of all pathways and receptors, as outlined previously, where other pathways may become critical to overall risk.

Point-of-exposure or exposure pathway measurements are applicable with respect to the following pathways.

Indoor Vapour Inhalation

Three main processes govern the vapour inhalation exposure pathway: partitioning of a volatile chemical from soil or groundwater to the vapour phase; vapour phase transport from the contaminant source to the soil adjacent to the building foundation; and infiltration/dilution between the soil and the building air. The direct measurement of soil vapour concentrations can reduce the uncertainty and conservatism in the generic modeling.

Modeling of the infiltration/dilution process is required to establish allowable vapour concentrations at the point of measurement that maintain the same protection level for receptors as adopted in Tier 1. Generic building assumptions are still required to avoid the necessity of land use restrictions. Other information will be required to support the use of point-of-exposure or exposure pathway measurements, including evidence that concentrations will not increase with time and that measurements are typical of the site-specific vapour concentrations expected from the contaminant of concern. In addition, where concentrations at depth are significantly greater than allowable Tier 1 concentrations, but are not generating significant concentrations at the building foundation, it may still be necessary to assess whether these concentrations result in other risks to receptors. For instance, risks for fire/explosive hazard, infrastructure impacts, aesthetic concerns, health of workers during excavation and construction etc may need to be re-evaluated for the contaminant of concern.

Depending on the site specific circumstances, the use of this technique may require implementation of a management plan to ensure materials remain at depth. This outcome would preclude the Tier 2 approach and require Exposure Control.

The modeling approach and relevant equations are presented in Appendix C.

Protection of Potable Groundwater, Groundwater Used by Livestock and Irrigation Water

The Tier 1 soil guidelines for the protection of potable groundwater and groundwater used for livestock watering or irrigation are based on a simple leaching-mixing-dilution model that describes the relationship between the chemical concentration in soil and that in the groundwater directly beneath the site. At Tiers 1 and 2, the point of compliance for the protection of potable water is anywhere within the Domestic Use Aquifer. The measured chemical concentration in the groundwater at the location of greatest risk for groundwater contamination may therefore be compared directly with the groundwater remediation guidelines, thereby lessening reliance on the assumptions involved in the dilution modeling.

This approach is considered a site-specific risk assessment and is always accompanied by a requirement for increased data gathering and long term groundwater monitoring as supporting evidence to ensure that groundwater concentrations will not increase over time.

Protection of Groundwater for Aquatic Life and Wildlife Watering

The derivation of Tier 1 values for the protection of aquatic life and wildlife watering utilizes lateral groundwater transport modeling with a default horizontal distance of 10 m which can be adjusted on a site-specific basis as described in the preceding section. Chemical concentrations measured in groundwater at the point of compliance or at any intermediate point along the transport pathway can be used to reduce the dependence on modeling. This, however, is considered a site-specific risk assessment and is always accompanied by a requirement for a more detailed understanding of the contaminant zone and a requirement for long term monitoring to verify predictions.

Some modeling will still be required. For zones other than the point of discharge, it will be necessary to model the time-dependent changes in concentration from the contaminant zone to the point of discharge. For measurements at the point of discharge, it is necessary to model the time dependent change in concentration at the point of discharge based on information from the contaminated zone. Similar conditions apply as above regarding evidence of stable or declining concentrations.

Requirements for Point-of-Exposure Monitoring

The use of point-of-exposure or exposure pathway measurements requires a scientifically defensible and consistent approach to sampling that ensures measured concentrations are representative of the appropriate point along the exposure pathway. In addition, modified modeling may be required to establish allowable concentrations at the measurement points. To ensure consistent application of this approach, specific sampling and modeling protocols are required. Since these are not presently specified in this document, point-of-exposure or exposure pathway measurements require progressing to more detailed site-specific risk assessments.

Appendix E Domestic Use Aquifer

The definition of a Domestic Use Aquifer (DUA) is given in Part A, Section 2.2.2. This appendix gives guidance on how the sustained yield may be calculated to determine if the aquifer of concern meets the definition of a DUA and provides guidance on when the DUA may be excluded.

E.1 Determining Sustained Yield for Defining a DUA

For a geologic unit to meet the definition of a DUA, it must have a bulk hydraulic conductivity of 1×10^{-6} m/s or greater and sufficient thickness to support a sustained yield of 0.76 L/min or greater. Bulk hydraulic conductivities must be determined using pumping test or slug test information from a sufficient number of piezometers/wells completed within the unit of interest. Unit thickness can be determined using site borehole information, and data from the Alberta Environment and Parks Water Well Record Database. Only a unit thickness greater than 0.5 m is considered in the determination of a DUA. Where thickness is less than this, the unit is automatically not considered a DUA regardless of the hydraulic conductivity. This is included in Figures 1 and 2 as the **minimum** thickness.

To simplify the determination of a DUA, Figure 1 shows a boundary curve with the **minimum** thickness required to meet the DUA condition for **confined aquifers** plotted against hydraulic conductivity. Geologic units meeting the DUA conditions plot on or above the line. This graph was derived using the Q_{20} equation (Farvolden method) and a range of representative values for aquifer thicknesses and available head.

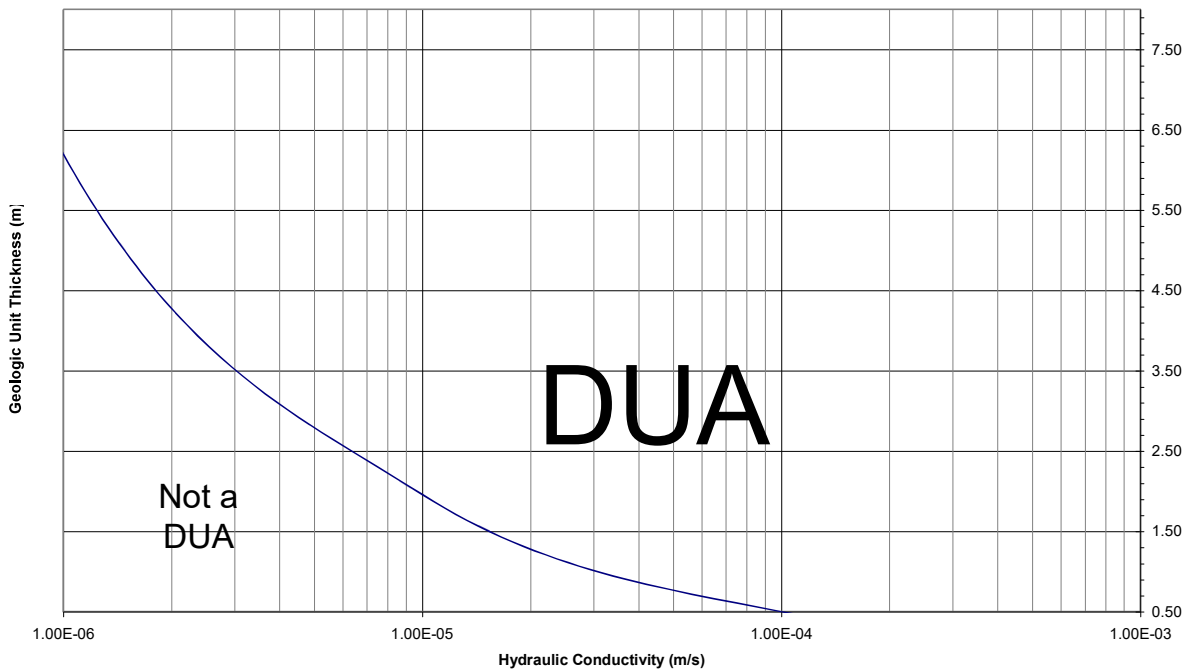


FIGURE 1. MINIMUM THICKNESS REQUIRED TO MEET DUA CONDITION FOR A CONFINED AQUIFER. SITE-SPECIFIC CALCULATIONS CAN BE MADE USING THE METHOD BELOW

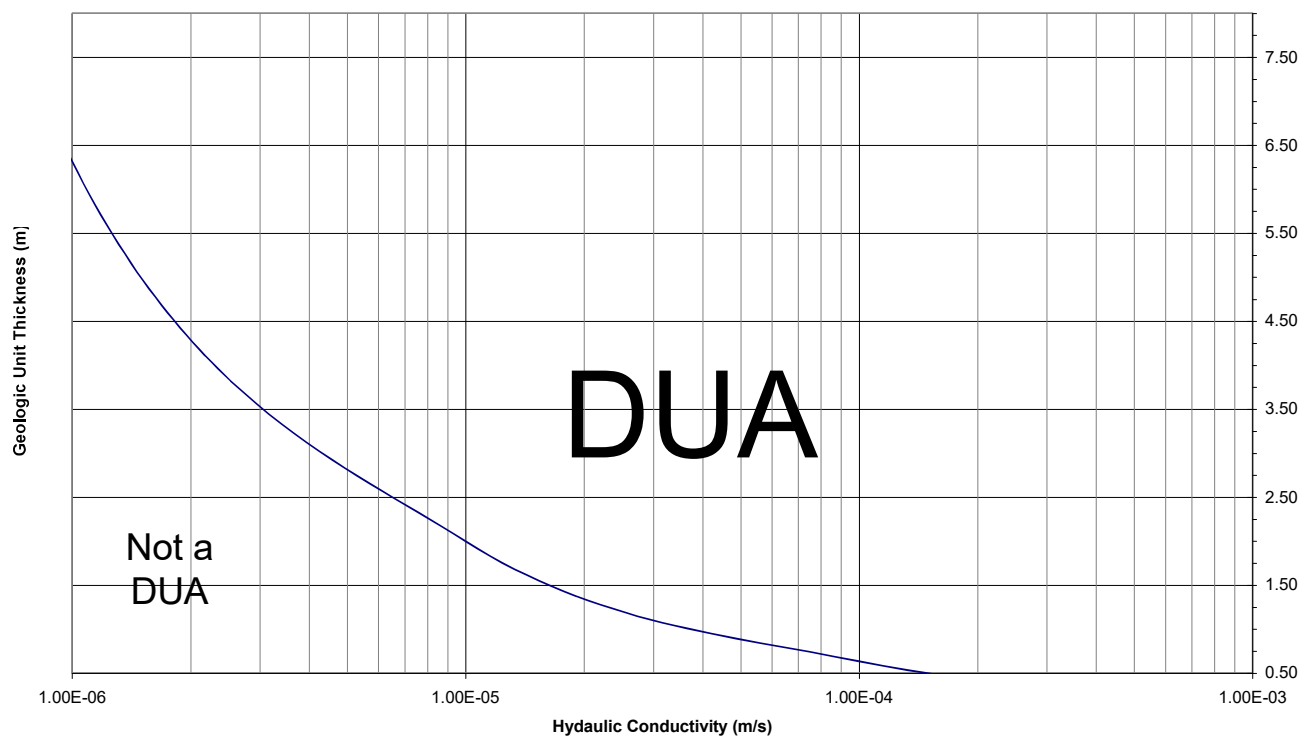


FIGURE 2. MINIMUM THICKNESS REQUIRED TO MEET DUA CONDITION FOR AN UNCONFINED AQUIFER. SITE-SPECIFIC CALCULATIONS CAN BE MADE USING THE METHOD BELOW

Figure 2 shows a boundary curve with the **minimum** thickness required to meet the DUA condition for **unconfined aquifers** plotted against hydraulic conductivity. Geologic units meeting the DUA conditions plot on or above the line. This graph was also derived using the Q_{20} equation (Farvolden Method) and a range of representative values for aquifer thicknesses.

E.2 Exclusion of the DUA Drinking Water Pathway by Geologic Barriers

Under a Tier 2 approach, if there is sufficient thickness of natural, undisturbed geologic material, acting as a barrier between the contaminant zone and the DUA, the drinking water pathway may be excluded. The objective of this approach is to maintain drinking water objectives within the DUA.

To exclude the DUA pathway, there must be:

1. At least 5 metres of massive, undisturbed, unfractured fine-grained material meeting appropriate guidelines with a bulk hydraulic conductivity that is less than or equal to 1×10^{-7} m/s, or
2. An equivalent thickness of natural, undisturbed geologic material that is more than 5 meters thick and is supported by technical information regarding the lithological properties prepared by the professional conducting the site assessment and accepted by Alberta Environment and Parks.

The conditions in (1) above may only be used for slightly soluble organic contaminants listed in Tier 1 and Tier 2 with a solubility equal to or lower than 10 g/L. A solubility list that is accepted by Alberta can be found in Table C-6 of the Tier 1 guidelines. Exclusion of the drinking water pathway for other substances, such as inorganic contaminants, metals, or more soluble organic contaminants, may be possible if supported by a site-specific risk assessment prepared in accordance with the Alberta SSRA Guide (GOA, 2022b). Supporting technical information regarding the lithological and substance properties must be prepared by the professional and accepted by Alberta Environment and Parks.

E.3 Special Considerations

Interbedded Geological Units

For the purpose of the definition of a DUA, both single lithological units and interbedded geological units must be considered. Many of the bedrock units in Alberta are composed of deltaic deposits, which as a result of the depositional environment are lenticular and discontinuous. Therefore, these units should be considered a single hydrostratigraphic unit.

Geologic Units Containing Large-Diameter Wells

Shallow, large diameter wells, also known as “bored wells,” are sometimes completed in geologic units that do not produce sufficient amounts of water to support a conventional water well. Typically, these geologic units do not meet the hydraulic conductivity or yield criteria for a DUA.

If large diameter wells are completed in a geologic unit that does not meet the hydraulic conductivity or yield criteria for a DUA, then the geologic unit should not be considered a DUA. In this case, the water well, including the draw down area, must be treated as a point of compliance, and must be handled using the Tier 2 Guidelines. The Tier 2 approach may be used to account for the lateral offset from the zone of contamination to the outer radius of the well's draw-down area.

Exclusion of the DUA in a Community with a By-law Prohibiting the Installation of Water Wells

Some communities and many municipalities have by-laws that prohibit the installation of water wells. Alberta's *Guide to Excluding the Domestic Use Aquifer (DUA) based on Municipal By-laws* (GOA, 2022a) clarifies the DUA pathway exclusion option for groundwater affected by a substance release at a location within the incorporated boundaries of a Municipality with a by-law prohibiting the installation of water wells. For further information on when and how this option can be used to exclude the Domestic Use Aquifer please see this guide.

Exclusion of the DUA in Peat and Muskeg Deposits

While it is possible that peat deposits and muskeg may meet the definition of a DUA, based on hydraulic conductivity and unit thickness, Alberta Environment and Parks does not consider peat deposits or muskeg to be a DUA because groundwater in them is unlikely to be used as a domestic source.

Shallow Saline Groundwater

Saline groundwater is defined, with respect to the DUA, as groundwater having a total dissolved solids content >4000 mg/L. Shallow groundwater may be saline in some parts of Alberta as a result of naturally occurring salts. Naturally saline groundwater is not considered a DUA. However, the presence of shallow saline groundwater does not preclude the potential for a DUA at deeper depths below the site. In order to exclude the DUA drinking water pathway, the approach outlined above in Section E.2 must be followed.

Calculation of Sustained Yield for Confined and Unconfined Aquifers

For a geologic unit to meet the definition of a DUA, it must have a bulk hydraulic conductivity of 1×10^{-6} m/s or greater and sufficient thickness to support a sustained yield of 0.76 L/min (1.2667×10^{-5} m³/s) or greater.

The long-term theoretical sustained yield is calculated using the **Farvolden Method**

$$Q_{20} = 0.68 * T * H_a * 0.7$$

$$T = K * b$$

Where: Q_{20} = the 20 year sustained yield (m³/s)

- T = transmissivity of the geologic unit (m^2/s)
- K = bulk hydraulic conductivity (m/s)
- b = thickness of the geologic unit (m)
- H_a = available head (m)

For confined aquifers, the available head (H_a) is equal to the distance between the non-pumping water level in the well prior to the pumping test and the top of the aquifer.

For unconfined aquifers, the available head (H_a) is chosen to be 2/3 of the difference between the base of the aquifer and the non-pumping water level in the well (or 2/3 the saturated thickness).