Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health

SITE-SPECIFIC GUIDANCE

Guidance Manual for Developing Site-Specific Soil Quality Remediation Objectives for Contaminated Sites in Canada

Canadian Council of Ministers of the Environment
The National Contaminated Sites Remediation Program
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Canadian Environmental Quality Guidelines
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Abstract

In response to a growing public concern over the potential environmental and human health-related effects associated with contaminated sites, the Canadian Council of Ministers of the Environment (CCME) initiated a five-year program in 1989 entitled the National Contaminated Sites Remediation Program (NCSRP) for remediation of high priority contaminated sites in Canada.

This report was prepared under this program to provide government environmental officers and site managers with guidance on the assessment and remediation of contaminated sites in Canada. A national framework for the assessment and remediation of contaminated sites has been developed to provide interested parties with general guidance on the use of the various common scientific tools that have been developed to support contaminated site assessment and remediation. More specific guidance on the use of each of these tools is provided in a series of technical reports that have been prepared for the NCSRP or are in preparation. Together, these tools provide virtually all of the technical guidance required to efficiently and effectively assess and remediate contaminated sites in Canada.

The CCME Subcommittee for Environmental Quality Criteria for Contaminated Sites recommends specific procedures for deriving remediation objectives for soil using the guideline-based approach. These recommendations include procedures for evaluating the applicability of the generic guidelines to individual contaminated sites and for modifying these guidelines to account for a typical or unique site characteristics. In addition, examples to illustrate the application of the recommended procedures for deriving site-specific remediation objectives have been presented. However, the procedures developed to support the derivation of remediation objectives are not intended to supersede management decisions taken under the authority of the agency responsible for remediation of a contaminated site.

Résumé

En réaction aux préoccupations croissantes du public quant aux effets écologiques et aux effets sur la santé humaine dus à l'exposition aux lieux contaminés, le Conseil canadien des ministres de l'environnement (CCME) a mis sur pied en 1989 un programme de cinq ans intitulé Programme national d'assainissement des lieux contaminés (PNALC), pour l'assainissement de lieux contaminés hautement prioritaires.

Ce rapport a été préparé dans le cadre de ce programme pour fournir des orientations aux autorités gouvernementales et aux gestionnaires de site sur l'évaluation et l'assainissement des terrains contaminés au Canada. Un réseau national d'évaluation et d'assainissement de lieux contaminés a été développé pour conseiller les parties intéressées sur l'utilisation d'outils scientifiques courants qui ont été élaborés pour appuyer l'évaluation et l'assainissement de lieux contaminés. Des informations plus spécifiques à chacun de ces outils sont disponibles dans une série de rapports techniques publiés, ou en voie de l'être, pour le compte du PNALC. L'ensemble de ces outils fournit pratiquement toute l'information requise pour évaluer et restaurer de façon efficace les lieux contaminés au Canada.

Le Sous-comité du CCME sur les critères de qualité environnementale pour les lieux contaminés a proposé des procédures spécifiques pour établir des objectifs d'assainissement des sols à partir de l'approche fondée sur les recommandations. Les propositions du Sous-comité incluent des procédures pour évaluer les possibilités d'application des recommandations génériques à un site spécifique et pour modifier ces recommandations en fonction des caractéristiques atypiques ou uniques du site. De plus, des exemples servent à illustrer l'application des procédures recommandées pour établir des objectifs d'assainissement propres à chaque lieu. Toutefois, les procédures ainsi développées pour appuyer l'élaboration d'objectifs d'assainissement n'ont pas pour but de remplacer et d'annuler les décisions de gestion prises par l'organisme responsable de l'assainissement d'un lieu donné.

Foreword

This report is a guidance manual for developing site-specific remediation objectives for contaminated sites designed to help provincial, territorial, and federal government staff, and other site managers as they address contaminated site remediation.

A general introduction to the scientific tools developed to help environmental quality managers in the assessment and remediation of contaminated sites in Canada is provided in Section 1. These tools were originally developed under the auspices of the CCME for the National Contaminated Sites Remediation Program (NCSRP). The framework in Section 1 explains how these scientific tools may be used at various stages in site remediation. One of the major tools will be the set of effects-based environmental quality guidelines, developed using *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* (CCME 1996a). It is intended that these generic guidelines will be applicable as the basis for remediation objectives at many sites. Some sites, however, may have conditions that require greater investigation before the generic guidelines are used as the basis for setting the remediation objective. Therefore, Section 2 provides guiding principles and explanations on when the generic guidelines may be adopted, when they may be modified, and when further investigation through risk assessment may be done. Section 3 provides a theoretical example of the recommended procedure.

This guidance manual is based on a review of similar guidance in other world jurisdictions combined with the cumulative experiences of environmental and human health managers in Canadian jurisdictions. The process described herein is still evolving as are the science and management of contaminated sites. Therefore, this guidance manual is expected to be revised in order to reflect new advances. Comments from readers are welcomed. In this way, the experience of others may lead to improved environmental management.

CCME Subcommittee on Environmental
Quality Criteria for Contaminated Sites

Acknowledgments

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This report is based on discussion, information, and guidance from members of the CCME Subcommittee on Environmental Quality Criteria for Contaminated Sites. The members include Dr. Connie Gaudet (Environment Canada), Dr. Lee Hofmann (Previous Chair, Ontario Ministry of Environment), M. Michel Beaulieu and Mme Renée Gauthier (Ministère de l'Environnement du Québec), Dr. Glyn Fox (B.C. Ministry of Environment), Ms. Simone Godin (New Brunswick Department of Environment), and Dr. Ted Nason (Current Chair, Alberta Environment). The Subcommittee members also thank Mr. Micheal MacFarlane (British Columbia Ministry of Environment) for comments on earlier drafts.

This final report has evolved based in part on discussions on an earlier report by Donald D. MacDonald (MacDonald Environmental Sciences Ltd.) and André Sobolewski (Microbial Technologies).

Glossary

Terminology with respect to contaminated site assessment may vary between individual jurisdictions and agencies. These terms are even used differently by the Canadian Council of Ministers of the Environment (CCME) in its various programs. The definitions here were adapted from CCME (1991a) and apply in the context of this guidance manual.

assessment criteria – approximate background concentrations or approximate analytical detection limits for contaminants in soil and water.

background concentration – representative ambient level for a contaminant in soil or water. Ambient concentrations may reflect natural geologic variations in relatively undeveloped areas or the influence of generalized industrial or urban activity in a region. Background concentrations should be determined from an area at the site under investigation, or at a nearby site, sufficiently removed from the source of contamination to be safely presumed to have been unaffected by contaminant release.

CCME Subcommittee on Environmental Quality Criteria for Contaminated Sites – a federal–provincial working group to advise on the development and application of scientific tools for the National Contaminated Sites Remediation Program. Herein referred to as the Subcommittee.

check mechanism – a subcomponent in the soil protocol that considers primarily cross-media transfers from soil to other media, pathways, or receptors.

contaminant – any chemical substance whose concentration exceeds background concentrations or that does not naturally occur in the environment.

criteria – generic numerical limits or narrative statements intended as general guidance for the protection, maintenance, and improvement of specific uses of soil and water. Previous CCME publications about the NCSRP used the term criteria; however, this term will be replaced by guidelines for consistency with other environmental media (water, sediments, etc.). Interim criteria refer to the CCME (1991a) set of values, which were adopted from other jurisdictions and are not effects-based.

final soil quality remediation objective (SQRO) – a numerical value for a substance; a remediation target that considers the recommended SQRO as well as technical, economic, and socio-political conditions.

guidelines – the numerical limits or narrative statements that are recommended to protect and maintain the specified uses of water, sediment, or soil. The guidelines that are developed in other CCME programs are functionally equivalent to the criteria used in the NCSRP.

interim criteria – the criteria that have either been adopted directly from existing criteria currently being used in other Canadian jurisdictions or derived using incomplete toxicological and/or environmental fate data sets as found in CCME (1991a). Interim criteria are reviewed and modified as new information becomes available.

modified soil quality remediation objective – the numerical value for a substance that uses the generic criteria as the basis for deriving a site-specific objective, is in the process of being cross-checked against the scientific considerations surrounding the human and environmental health conditions at the site, but has not yet been put forward as the recommended soil quality remediation objective.

NCSRP – the CCME National Contaminated Sites Remediation Program.

objective – a numerical limit or narrative statement that has been established to protect and maintain a specified use of soil or water at a particular site by taking into account site-specific conditions. Unless otherwise specified, objectives refer to the concentration of a substance in bulk soil.

orphan site – a contaminated site for which the responsible party cannot be identified or appears to be incapable of initiating or unwilling to initiate remedial measures.

parameter – an element in an equation, the value of which may be modified at the site-specific level within limits. Parameters that may be modified include organic carbon levels in soil that affect attenuation of organic contaminants, and body weight or soil ingestion rate of human receptors.

polluter pays – the principle that the polluter is responsible for correcting or remediating whatever environmental degradation his or her actions have caused.

proponent – the principal party responsible for the site remediation.

recommended soil quality remediation objective – the numerical value for a substance that reflects cross-checking of the scientific considerations surrounding the human and environmental health conditions at the site. The recommended value, together with documentation on how it was determined, is put forward as the starting point in determining a cleanup target that considers environmental and human health as well as technical, economic, and socio-political conditions.

remediation –the management of a contaminated site for prevention, minimization, or mitigation of damage to human health or the environment. Remediation options may include, but are not limited to, direct physical actions, such as treatment, removal, or destruction of contaminants, or other on-site risk management solutions, such as capping or containment of contaminants.

remediation guidelines – guidelines that are intended for generic use and do not address site-specific conditions. They are considered generally protective of human and environmental health for specified uses of soil and water at contaminated sites.

site – a property or legal parcel of land, that may include adjacent legal properties when affected by off-site movement of contaminants.

soil protocol – *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* (CCME 1996a). Herein referred to as the soil protocol.

SQG_E and SQG_{HH} – the soil quality guidelines considering "environmental effects" and those considering "human health" effects, respectively, as put forward under the soil protocol.

standard – a legally enforceable numerical limit or narrative statement, such as in a regulation, statute, contract, or other legally binding document, that has been adopted from a criterion or an objective.

1.0 OVERVIEW OF THE NATIONAL CONTAMINATED SITES REMEDIATION PROGRAM

1.1 Background

In 1989, the Canadian Council of Ministers of the Environment (CCME) announced the National Contaminated Sites Remediation Program (NCSRP) to address human health and environmental quality concerns at contaminated sites in Canada. This federal–provincial/territorial program was intended to support the assessment and remediation of contaminated sites by providing a common framework and scientific tools for the consistent, scientifically defensible, and cost-effective assessment and remediation of contaminated sites. Specifically, it was intended to:

- review and establish legislative instruments to ensure that the "polluter pays" principle is respected;
- establish a consistent scientific basis for the identification, assessment, and remediation of sites;
- support the remediation of "orphan" sites where the polluter-pays principle cannot be enforced;
- provide funding for technological advancements in remediation methods; and
- communicate with stakeholders who are interested in, or affected by, the remediation of contaminated sites.

1.2 The National Contaminated Sites Remediation Program's Approach

In April and November of 1990, the CCME held multistakeholder workshops to discuss key factors developing a national framework for dealing with contaminated sites. Three key recommendations from these workshops indicated the need for:

- a "tiered" approach to assessment and remediation with generic national criteria and guidance on site-specific objectives;
- a consistent risk-based approach to evaluate and set priorities for remediation of contaminated sites; and

- equal protection of human health and the environment.

Workshop participants also indicated that effective implementation of these major program objectives would require the development of a number of supporting scientific tools.

As a result of the workshops, the CCME established the Subcommittee on the Classification of Contaminated Sites and the Subcommittee on Environmental Quality Criteria for Contaminated Sites. Together these subcommittees have initiated a broad range of scientific tools, including:

1. *Interim Canadian Environmental Quality Criteria for Contaminated Sites* (CCME 1991a)

2. *National Classification System for Contaminated Sites* (CCME 1992)

3. *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* (CCME 1996a)

4. *Guidance Manual for Developing Site-specific Soil Quality Remediation Objectives for Contaminated Sites in Canada* (CCME 1996) [this document]

5. *A Framework for Ecological Risk Assessment at Contaminated Sites in Canada: Review and Recommendations* (EC 1994a) and *A Framework for Ecological Risk Assessment: General Guidance* (CCME 1996b)

6. *A Review of Whole Organism Bioassays for Assessing the Quality of Soil, Freshwater Sediment and Freshwater in Canada* (EC 1994b)

7. *Evaluation and Distribution of Master Variables Affecting Solubility of Contaminants in Canadian Soils* (Alder et al. 1994)

8. *Human Health Risk Assessment for Contaminated Sites* (HC 1995)

In addition to these tools, other CCME and federal government documents may help the site manager in the assessment and remediation of contaminated sites in Canada. These include:

1. *National Guidelines for Decommissioning Industrial Sites* (CCME 1991b)

2. *Guidance Manual on Sampling, Analyses, and Data Management for Contaminated Sites.* Vol. I: Main Report; Vol. II: Analytical Method Summaries (CCME 1993a)

3. *Subsurface Assessment Handbook for Contaminated Sites* (CCME 1994)

4. *Canadian Water Quality Guideline*s (CCREM 1987)

5. *A Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life* (CCME 1991c)

6. *Protocols for Deriving Water Quality Guidelines for the Protection of Agricultural Water Uses* (CCME 1993b)

7. *Protocol for the Derivation of Canadian Sediment Quality Guidelines for the Protection of Aquatic Life* (CCME 1995)

8. *Protocol for the Derivation and Use of Canadian Tissue Residue Guidelines for the Protection of Wildlife in Aquatic Ecosystems* (Walker and MacDonald 1993)

Together, these tools provide the key supporting scientific information that is available for assessing and remediating contaminated sites in Canada. **The guidance on setting site-specific objectives for contaminated sites provides a context for these tools and is intended to be used together with these tools in the contaminated site assessment and remediation process.**

1.3 National Framework for Assessment and Remediation of Contaminated Sites

The basic framework for site assessment and remediation (originally developed under the NCSRP) consists of progressing from the generic to the site-specific: from guidelines through objectives to jurisdictional application (Figure 1). Jurisdictional applications may include, but are not limited to, environmental protection orders, directives, approvals, or standards.

The national framework for assessment and remediation of contaminated sites is more detailed (Figure 2). As indicated, this guidance manual focuses on the development of site-specific objectives from generic environmental quality guidelines. As well, conditions where site-specific risk assessment may be appropriate are outlined.

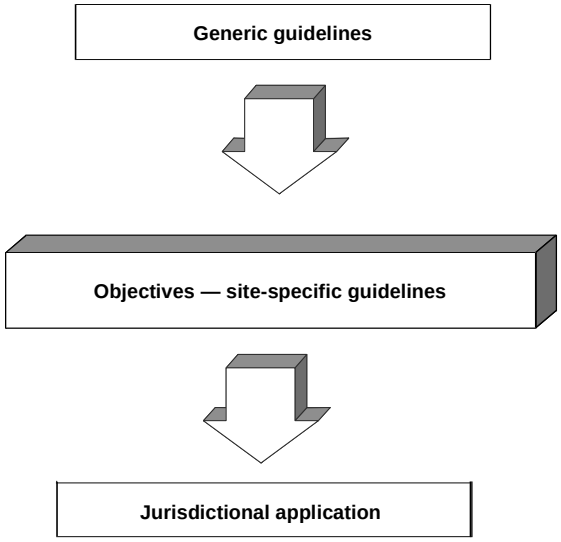

Figure 1. General approach for contaminated site assessment and remediation.

1.3.1 Nomination of Contaminated Sites

The first step in the overall contaminated site assessment and remediation process is the nomination of sites for consideration. In general, this tends to be a relatively informal procedure that is implemented by jurisdictional agencies. For example, federal or territorial agencies may have information suggesting that sites under their jurisdiction have been contaminated by historical land use activities.

Likewise, provincial agencies may nominate candidate sites directly or may consider nominations from third-party interests. Typically, these sites would be identified based on information demonstrating that the site is significantly contaminated (e.g., soil chemistry data). However, any newly identified site may also be nominated if it has a number of similarities to other known contaminated sites. Sites nominated under the NCSRP were classified, using the National Classification System, to assess the need for further action to mitigate risks to human health and the environment. The classification system has general application beyond the NCSRP.

1.3.2 National Classification System for Contaminated Sites

Site classification is an important component of the overall contaminated site assessment and remediation process. In Canada, a national classification system for contaminated sites (CCME 1992) has been developed to provide a simple, consistent, and reliable basis for classifying sites in terms of the potential risks they represent to the environment and human health. The system provides a convenient basis for assessing the need for remediation at individual sites, for establishing the relative priority for implementing remedial measures among the sites that have been classified, and in the case of the NCSRP, for determining whether individual sites qualify for NCSRP funding. This classification system was specifically developed for the classification of sites having contaminated soils and groundwater. Detailed guidance on the use of the National Classification System is provided elsewhere (CCME 1992); therefore only a brief overview of this system is provided here. To complete the classification, information about the site is required (see the Appendix).

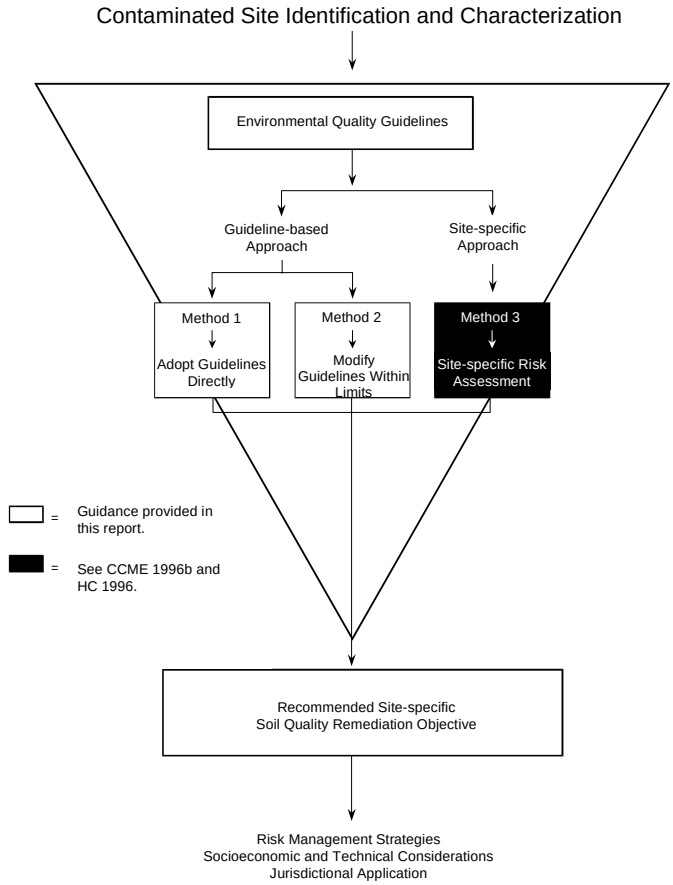

Figure 2. National framework for contaminated site assessment and remediation.

Classification of contaminated sites using the National Classification System is a five-step process that requires technical expertise and professional judgement (see Figure 3).

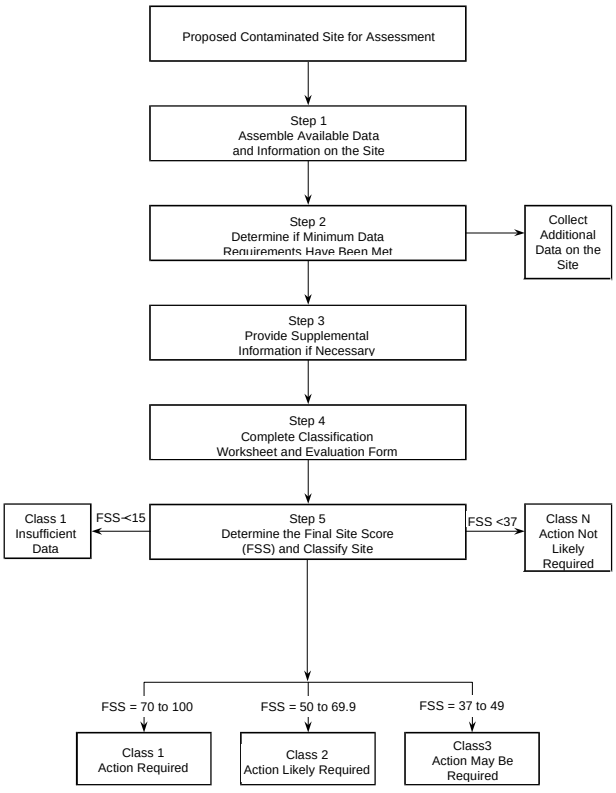

Figure 3. The national classification system for contaminated sites (source: CCME 1992).

Step 1

Assemble the available information on the site under consideration.

Step 2

Critically evaluate information to determine if the minimum data requirements for site classification have been met. Information required includes:

- a description of the site (location, size, etc.);
- the nature and extent of contamination (and/or historical activities);
- the local topography and geology;
- the surface cover;
- approximate depth to water table;
- proximity to surface water and drinking water supplies;
- annual rainfall, and flood potential; and
- land and water use information, both at the site and in nearby areas

If all of the requisite data are available, it is possible to proceed with the site classification. If not, additional data must be collected at the site to obtain the missing information.

Step 3

Though the classification system was designed to use generally available information, it may be necessary to generate supplemental information on the contaminated site, if the checklist in Step 2 cannot be completed. While common environmental survey techniques are appropriate for collecting much of the required data at contaminated sites, sampling programs to establish the nature, extent, and severity of contamination at these sites must be designed to generate data of sufficient quality and quantity to support the site classification.

In response to the need for high quality data, the CCME has prepared a guidance manual to support sampling, chemical analysis, and data management in the NCSRP (CCME 1993a). While this manual provides a consistent basis for conducting data collection programs (including sampling and chemical analysis), medium-specific protocols (i.e., for water, sediment, and soil) that have been developed for broader applications should also be considered in the design and implementation of monitoring programs (e.g., CCME 1994; ASTM 1990; Mudroch and MacKnight 1991; other provincial manuals). Implementation of a focused, well-designed monitoring program will ensure that the resultant data will support a reliable site assessment.

Step 4

Evaluate the nature, severity, and extent of contamination; determine the probable exposure pathways; and assess the sensitivity of the receptors at the site (by completing the site evaluation forms; CCME 1992). The Facility/Site Description and the Site Classification Worksheet allow you to organize and document the raw information needed to identify and classify the site. The generic environmental quality criteria developed under the NCSRP (CCME 1991a) and other CCME programs (CCREM 1987) are used in this process to assess the severity of contamination and the hazards posed to receptors at the site.

Step 5

Check the Detailed Evaluation Form to be sure all of the required factors were considered during the site classification. The rationale for selecting the score for each factor is fully documented on the worksheet. Tally the final site score on the evaluation form and use the final site score to classify the site.

Possible Classifications Using the National Classification System

Depending on the final site score, contaminated sites are placed into one of five categories, namely:

- Class 1: action required
- Class 2: action likely required
- Class 3: action may be required
- Class N: remedial action not needed
- Class I: insufficient data

Specific management actions that may be taken at these sites include further characterization, hazard assessment, risk assessment, and/or remediation. Classification of contaminated sites in this manner provides an effective screening tool for determining the relative priority that should be placed on individual sites. In addition, the information collected and evaluated during the site classification process may be used to focus detailed investigations at high priority sites, such as those that might be associated with an environmental or human health risk assessment. Furthermore, this information may be used to identify use-protection goals and priority contaminants at the site, in the derivation of site-specific remediation objectives, and in the development of the site management strategy.

1.3.3 Generic Environmental Quality Criteria

Assessment Criteria. In 1991, the CCME recommended interim environmental quality criteria for soil and water to address the immediate need for management tools to support the assessment and remediation of contaminated sites (CCME 1991a). In general, criteria are used as general guidance for the protection, maintenance, and improvement of specific uses of soil and water. Assessment criteria are approximate background concentrations or approximate analytical detection limits for contaminants in soil or water. Generally, the assessment criteria are applied in identifying and classifying sites, to assess the general degree of contamination at a site, and to determine the need for further action. If concentrations of a substance in the soil or water at a site do not exceed the assessment criteria, further action is not usually required. When concentrations exceed assessment values, investigative action should be considered to assess the extent of contamination and the nature of any hazards at a site, and to determine the scale and urgency of further action, if required. These criteria are a general first approximation only.

Interim Remediation Criteria. The interim remediation criteria are considered generally protective of human and environmental health for specified uses of soil and water at contaminated sites, based on experience and professional judgement, and on a review of guidelines and criteria from other Canadian jurisdictions. Together, the interim environmental quality criteria for contaminated sites and the generic environmental quality criteria from other CCME programs (CCREM 1987; CCME 1991c, 1993b; 1995) provide a consistent basis for assessing the degree of contamination at specific sites and for determining the need for remedial action. The interim criteria are not effects-based and are recommended for use until effects-based replacements become available.[1]

Environmental and Human Health Soil Quality Guidelines. The 1990 multistakeholder workshops highlighted the urgent need for a consistent and defensible approach to setting national remediation criteria for soil. Such protocols were already developed or under development as part of existing CCME programs for water (HWC 1989; CCME 1991c, 1993b), sediment (CCME 1995), and biological tissues (Walker and MacDonald 1993). The soil protocol (CCME 1996a) provides a consistent method for deriving soil quality guidelines under defined exposure scenarios for ecological and human receptors. The exposure pathways and receptors that were considered under the four land-use categories are shown in Table 1. Until remediation guidelines developed using the soil protocol are available, site managers should use the interim Canadian Environmental Quality Criteria (EQC) for soil and water. The other CCME guidelines may be used as appropriate.[1]

Effects-based Guidelines. Remediation criteria or guidelines can be used as generic benchmarks to evaluate the need for further investigation or remediation with respect to a specified land use. Canadian Council of Ministers of the Environment remediation guidelines are available for agricultural, residential/parkland, commercial, and industrial land uses. The degree by which

[1] Note that because the interim remediation criteria were not developed, using the soil protocol and its integral checks, they cannot be modified or deconstructed as shown in Figures 4, 5, and 6. If in the absence of effects-based criteria, interim remediation criteria are to be used as the basis for developing site-specific objectives, a number of factors may nonetheless be considered. The factors include, but are not limited to, background levels of the substance in soil, social, economic, and technological concerns.

Table 1. Receptors of concern considered for the derivation of effects-based soil quality guidelines for the National Contaminated Sites Remediation Program (CCME 1996a).

Route of exposure	Agricultural	Residential/ parkland	Commercial	Industrial
Soil contact	• crops/plants • invertebrates • nutrient cycling processes • livestock/ wildlife	• plants • invertebrates • nutrient cycling processes • wildlife	• plants • invertebrates • nutrient cycling processes	• plants • invertebrates • nutrient cycling processes
Soil and food ingestion	• livestock/ wildlife			
Multimedia exposure (human health)	• child	• child	• child	• adult

contaminant levels at a site exceed these benchmarks reflects the scale and urgency of further action. Where it is not feasible to remediate the site due to technological or other constraints, the remediation guidelines can also provide guidance on the need for land use restrictions or other forms of risk management to protect human health and the environment.

The principal application of the remediation guidelines, however, is to provide the common basis for the establishment of site-specific remediation objectives. Moving from the generic guidelines to a site-specific remediation objective allows the proponent to ensure that the assumptions used in the soil protocol apply to the site-specific conditions.

Depending on local circumstances, the guidelines may be adopted directly (Method 1) or modified within limits to reflect site-specific conditions (Method 2). In either case, once guidelines are applied at the site-specific level in this way, they become remediation objectives.

In Canada, generic environmental quality remediation guidelines (or criteria, as they were usually termed in previous CCME publications about the NCSRP) from various CCME programs are derived to protect the most sensitive life stages of the most sensitive receptors that inhabit soils, sediment, or water. For soil, the soil protocol sets out conservative calculation procedures for the protection of human health and the environment under agricultural, residential/parkland, commercial, and industrial land uses. For this reason, the generic remediation guidelines tend to be conservative values that are protective of a wide range of receptors under a diverse array of potential environmental conditions. When adopted as remediation objectives on a site-specific level, these generic guidelines provide an effective basis for protecting and restoring designated land and water uses at contaminated sites.

1.3.4 Guidance on Developing Site-specific Environmental Quality Objectives

This report describes the core set of scientific tools available to assess environmental quality staff as it relates to the national framework for the assessment and remediation of contaminated sites from site classification to development of environmental quality remediation objectives (Figure 2). Chapter 2 outlines adopting generic guidelines (Method 1), the modification of generic guidelines within limits (Method 2), and conditions where site-specific risk assessment (Method 3) may be recommended. Finally, Chapter 3 gives an illustration of the overall process and the use of the various scientific tools using a theoretical example.

Many contaminated sites also contain discrete waste material and products. It should be noted, that remedial objectives for soil and groundwater apply primarily to contaminated environmental media that remain on site after the removal and management of the discrete waste material.

As the generic soil quality guidelines are intended to provide a high level of protection for the designated land uses, they are considered to be broadly applicable to soils in this country. Therefore, these generic remediation guidelines are likely to serve as the basis for setting soil quality remediation objectives at most contaminated sites. Although the generic guidelines are appropriate for use under a wide range of environmental conditions, site-adapted environmental quality remediation objectives may be necessary under certain circumstances, such as at sites having atypical characteristics (e.g., high natural background levels of a contaminant), complex mixtures of contaminants (that could act synergistically or antagonistically), or unusual exposure scenarios (e.g., the presence of special populations or receptors). Two basic approaches have been proposed to support the development of site-specific remediation objectives in Canada. The first approach, known as the *criteria-based approach*, involves

- Method 1: direct adoption of existing Canadian soil remediation guidelines, or
- Method 2: limited modification of the soil remediation guidelines to reflect site conditions.

The second approach, termed the *risk-based approach*, relies on

- Method 3: use of risk assessment procedures to establish the remediation objectives at contaminated sites on a site-specific basis.

For some sites, the direct adoption of the generic guidelines may be appropriate. In other cases, it may be appropriate to modify the generic guidelines. This guidance manual describes how check procedures—the subcomponents within the soil protocol that consider primarily cross-media transfers of contaminants—may either be considered or disregarded under site-specific conditions (Method 2). The parameters within certain equations that may be modified to reflect site-specific conditions are also listed. Site proponents should be aware that information in this report is guidance only and that the authority to accept the changes to equation parameters using site-specific data remains with the appropriate jurisdiction.

The site manager is referred to guidance manuals on ecological risk assessment (CCME 1996b) and human health risk assessment (HC 1995) for more detail on the application of risk assessment (Method 3).

The Criteria-based Approach. The criteria-based approach entails adoption or limited modification of generic guidelines in light of prescribed site-specific factors affecting contaminant mobility and receptor characterization. Previous CCME publications about the NCSRP used the terms soil criteria; however, the term criteria will be replaced by guidelines for consistency with other environmental media (water, sediments, etc.). Nevertheless, this approach will still be referred to as "criteria-based approach".

Under the criteria-based approach, modification of generic soil quality guidelines for individual contaminated sites in Canada necessitates the consideration of at least four factors (Figure 4), including:

- natural background levels of priority substances;
- possible movement of contaminants in soil to groundwater, air, or dust;
- relevance of the toxicological data that were used to derive the generic guidelines to the site under consideration (e.g., the human and ecological receptors); and
- land uses and receptors of concern under those land uses.

Limited Modification. Figure 5 shows that limited modification of equation parameters may be allowed for

- groundwater protection;
- human exposure to soil; and
- direct soil contact by ecological receptors.

Removal of Management Checks. The check procedures within the soil protocol that may or may not be deemed appropriate at the site-specific level include:

- backyard gardens in residential/parkland land use;
- dairy or grain production for human consumption in agricultural land use;
- volatile organic compounds in basements of residential/parkland land use;
- off-site movement of dust from industrial land use; and
- background concentrations.

The CCME recognizes that the check procedures used in the soil protocol are elementary. However they were deemed an appropriate level of detail for developing generic guidelines. More sophisticated and complex models exist and may be appropriate at a site-specific level; however, the CCME recommends that these more complex models be addressed under a risk-based approach.

Other factors at contaminated sites that could alter the use of the generic guidelines as remediation objectives may also be identified. These factors should be evaluated on a case-by-case basis within the appropriate jurisdiction, with professional judgement being exercised by the jurisdictional authority in deciding whether to permit modification of the generic guidelines. In contrast to risk assessment, the criteria-based approach is designed to require fewer resources while providing a scientifically defensible basis for protection that is sufficiently flexible to account for certain site-specific factors.

The Risk-based Approach. The risk-based approach is a complex and time-consuming procedure that involves at least the following steps:

- Evaluation of the hazard and risk from contaminants to receptors on a site-specific basis and comparison of the

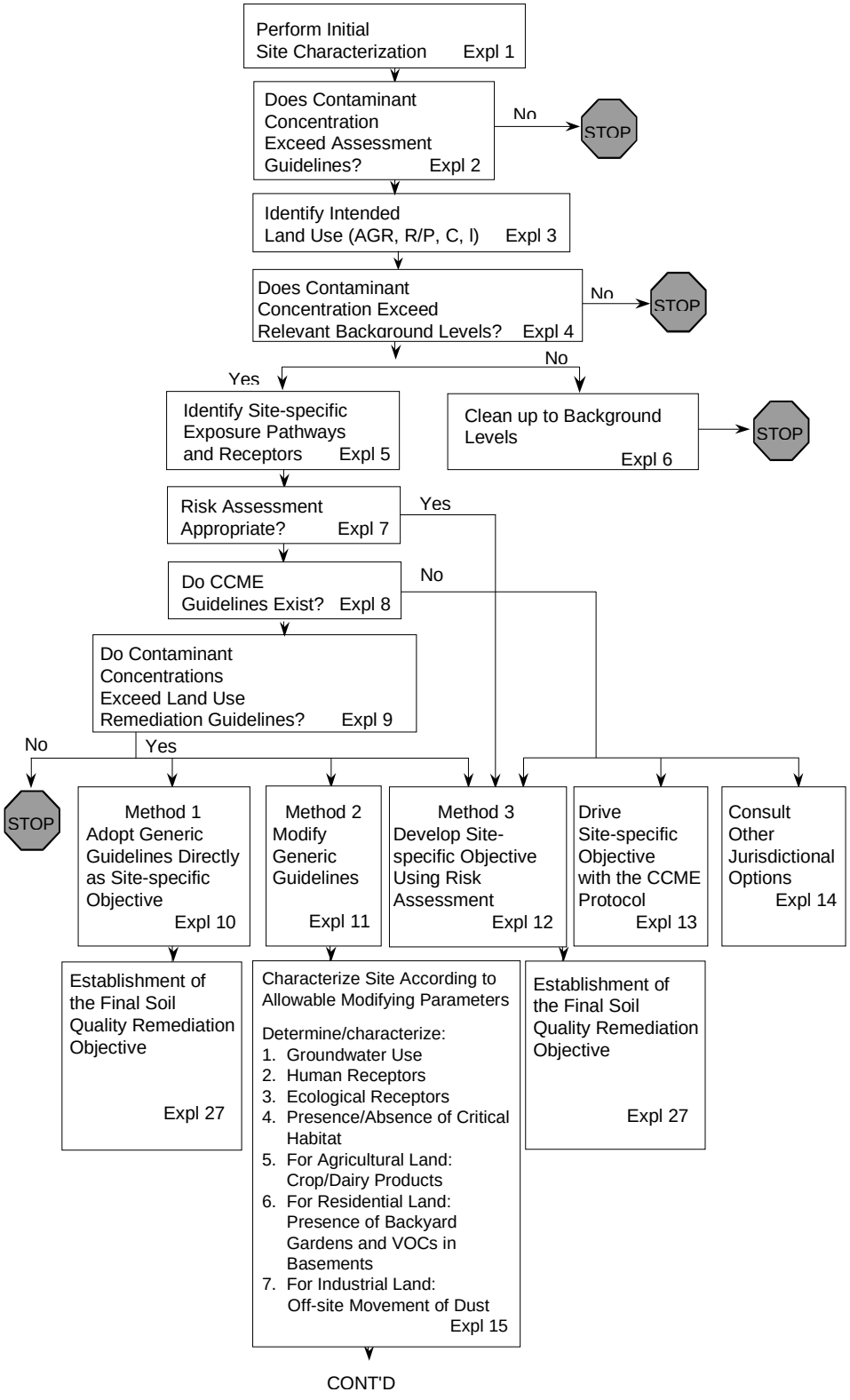

Figure 4. Flowchart for setting site-specific soil quality remediation objectives for contaminated sites.

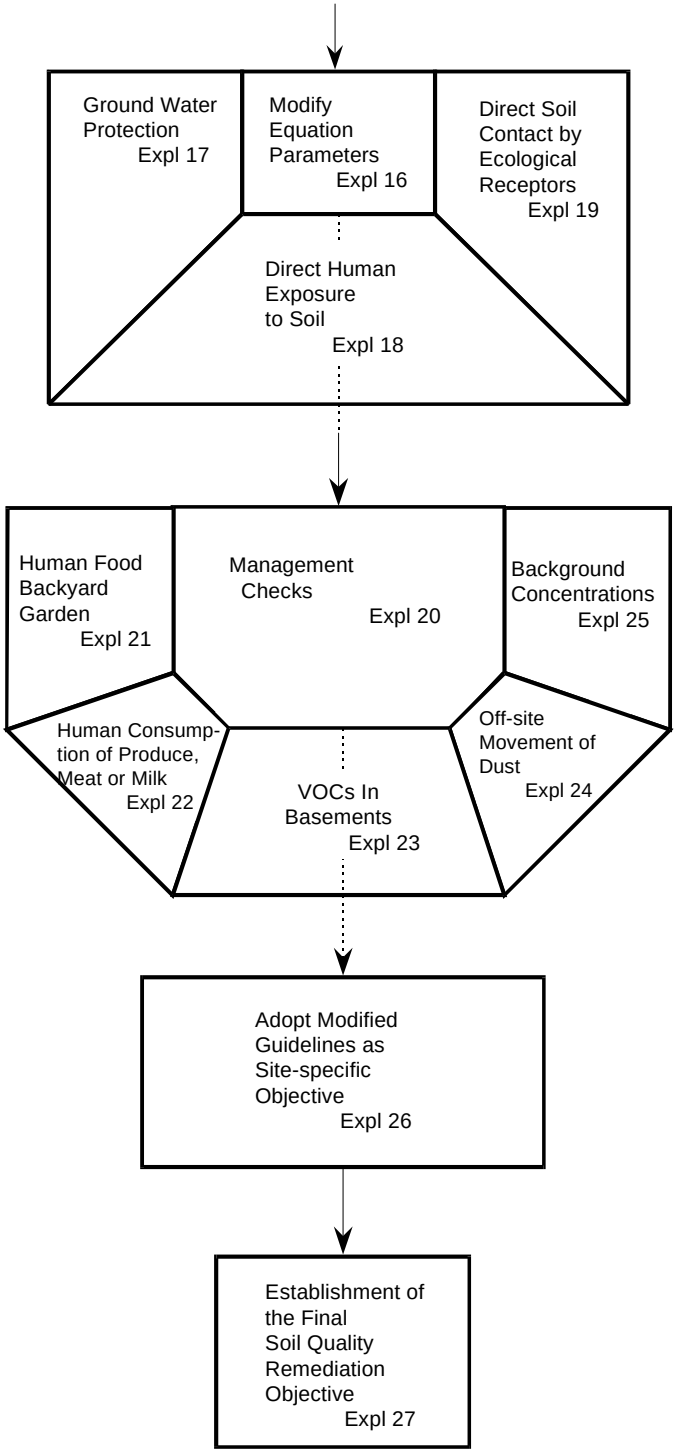

Figure 4. Continued.

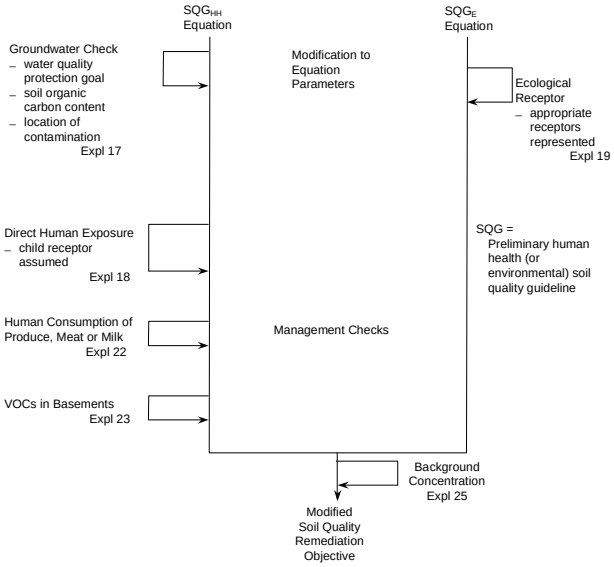

Figure 5a. Agricultural land use.

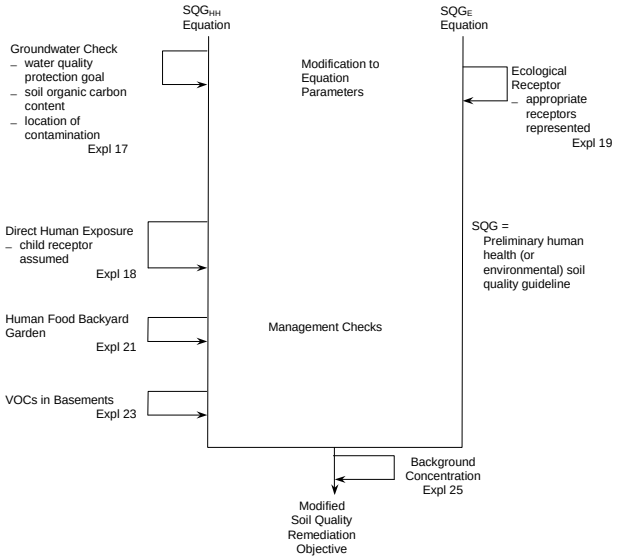

Figure 5b. Residential/parkland land use.

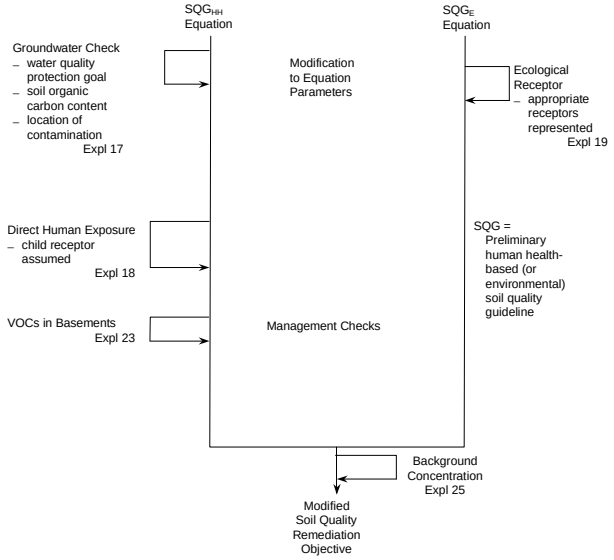

Figure 5c. Commercial land use.

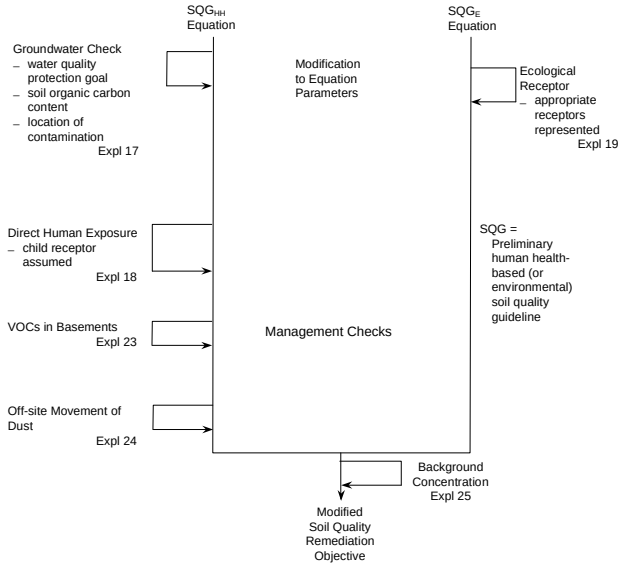

Figure 5d. Industrial land use.

calculated values to an "acceptable risk" guidelines to determine an appropriate remediation objective

- Design and implementation of a risk management plan to address site-acceptable risk/remedial objective exceedance

The hazard and risk evaluation steps are complex and involve receptor characterization, exposure assessment, hazard assessment, and risk characterization. A risk assessment of considerable complexity may be required before sufficient information and understanding will allow the recommendation of site-specific risk-based

remediation objectives. This approach requires a considerable commitment of experienced personnel, equipment, time, and money.

Risk assessment guidance manuals (CCME 1996b) provide guidance on the circumstances under which risk assessment may be the most appropriate means of setting site-specific objectives. The criteria-based approach is believed to provide an effective scientifically based conservative alternative to a detailed risk assessment.

1.3.5 Selection of Recommended Approaches for Modifying Guidelines

The approaches recommended in this book have evolved, in part, from a review by MacDonald and Sobolewski (1993) of existing approaches for formulating and modifying generic soil quality guidelines and site-specific remediation objectives. The approaches were considered if they were

- practical, i.e., supported the modification of generic guidelines or the derivation of remediation objectives;
- applicable to the NCSRP, i.e., supported the derivation of objectives for remediating contaminated sites and assessing compliance with the remediation plan; or
- scientifically defensible in terms of their ability to incorporate information on bioavailability, biological effects, complex mixtures of contaminants, and site-specific conditions.

2.0 RECOMMENDED PROCEDURES FOR DERIVING SITE-SPECIFIC SOIL QUALITY REMEDIATION OBJECTIVES

The process of developing numerical soil quality remediation objectives necessitates the appropriate use of general and site-specific information. Guiding principles have been established to direct and focus this process. The guiding principles, which follow, are intended to provide guidance relevant to specific conditions and decisions common to most contaminated sites. It is recognized, however, that sound professional judgement will play a critical role in the interpretation and application of these guiding principles at the site-specific level.

2.1 Guiding Principles

The following guiding principles for the development of numerical soil quality remediation objectives for contaminated sites in Canada are based on the philosophy established by CCME (1991a, 1996a):

1. Site-specific soil quality remediation objectives should be protective of human health and the environment.

2. Site-specific soil quality remediation objectives should be protective of the appropriate land use at a contaminated site.

3. The land uses to be considered for protection include agricultural, residential/ parkland, commercial, and industrial.

4. It is the philosophy of the CCME to encourage remediation to the lowest level practicable, considering the intended land use and other factors, such as technological limitations. Environmental quality guidelines are not intended to establish maximum levels of contamination acceptable at contaminated sites. Where the quality of site conditions is considered superior to the Canadian environmental quality guidelines, degradation of existing site conditions should be avoided.

5. Generic soil quality guidelines for a substance may be adopted directly (Method 1) as the recommended soil quality remediation objective for the intended or likely future use of a remediated contaminated site in Canada. Where it can be demonstrated that the guidelines are not applicable or appropriate to the specific site in question using the evaluation guidelines that follow, the guidelines may be modified within the limits prescribed in this guidance manual (Method 2). In some circumstances, the risk-based approach (Method 3) may be deemed more appropriate to determine site-specific remediation objectives.

6. If generic soil quality guidelines for the designated land use at a contaminated site are not available, the proponent should consult the jurisdictional authority. Options for guidelines development may include, but are not limited to, using risk assessment to develop remediation objectives, using the soil protocol (CCME 1996a) to develop remediation objectives, adopting appropriate background levels as remediation objectives, or adopting guidelines from other jurisdictions as remediation objectives.

7. The explanations in this chapter specify the recommended conditions and procedures under which it is appropriate to modify generic guidelines or to develop risk-based remediation objectives.

8. The approach used to modify soil quality guidelines should adhere to the soil protocols and minimum data requirements established in the soil protocol (CCME 1996a) and the guidance documents relating to the criteria-based (this document) and risk-based approaches (CCME 1996b and HC 1995).

9. Generic soil quality guidelines were developed using information on defined exposure scenarios in Canada. Limited modification may be allowed to the parameters in three equations, and management check procedures may or may not be applicable. Apart from the equation and management check procedures specified in this guidance manual, the exposure scenario assumptions should not be altered without permission from the jurisdictional authority when using the criteria-based approach. However, these assumptions may be altered if the recommended soil quality remediation objective was modified using the risk-based approach.

10. Recommended soil quality remediation objectives may be modified within limits by omitting toxicological data on terrestrial organisms (e.g., annelids, arthropods) if it can be demonstrated by the proponent that specific toxicity data used to derive the national generic guidelines are not relevant to the site under investigation. Under such conditions, the generic guidelines may be modified by recalculating them based on an adjusted data set derived by eliminating toxicological information not relevant to the site under investigation, provided that

    - the minimum data requirements for deriving generic soil quality guidelines in the soil protocol (CCME 1996a) are met; and
    - the administrative rules set out in Explanation 19 are followed.

11. Recommended soil quality remediation objectives (RSQRO) should normally be protective of the most sensitive water use associated with the groundwater at or near the contaminated site.

12. Each decision to accept or reject modification of the RSQROs should be carefully documented and justified.

13. In general, the Subcommittee recommends that socioeconomic and technical feasibility factors be considered in detail in developing a risk management strategy. The framework presented in this guidance manual provides for consideration of socioeconomic and technological factors after an RSQRO has been developed, using either the criteria-based or risk-based approach. Guidance on socioeconomic and technical feasibility factors is, however, outside the scope of the Subcommittee.

14. Continued contamination of the site from readily identifiable sources (pits, ponds, lagoons, leaking storage tanks, etc.) should be prevented while detailed site investigations are conducted to support the development of site-specific soil quality remediation objectives using either the criteria-based or risk-based approach. Under these circumstances, the generic soil quality guidelines, modified using the available information, may be used to guide the remedial action.

2.2 Explanations

The following explanations are to be used in conjunction with Figure 4.

Explanation 1: Initial Site Characterization

Information on the nature of the site, including the current and historical activities, should be reviewed. *National Guidelines for Decommissioning Industrial Sites* (CCME 1991b) presents a two-phase site characterization schedule. Phase I is a site information assessment that consists of assessing the historical and current activities or practices that may have resulted in environmental contamination. Phase II is a reconnaissance testing program that characterizes the types and concentrations of

contaminants present in various media on the site. This information will indicate whether more detailed testing is required in specific areas and will provide the initial inputs required to develop appropriate site cleanup guidelines. The reconnaissance testing program should target known and suspected areas of site contamination identified in Phase II, as well as areas believed to be relatively unaffected by site operations. In cases where contamination is suspected near site boundaries or is known to have moved off site (such as by aeolian, groundwater, or surface water transport), samples should be collected to assess off-site effects, potential liabilities, and remediation requirements. The components of Phase I and Phase II investigations follow; however, readers are directed to CCME (1991b) for further information. Procedures may also be available through the jurisdictional authority.

Phase I: Site Information Assessment

Historical and Current Setting – topography, geology, soils, terrestrial habitats, vegetation, surface water quality, groundwater and surface water quality, site layout, wastewater ponds, raw water reservoirs, pipelines, underground tanks, buried service lines, foundations, shipping/receiving areas, storage areas, spill areas, roads and rail lines, atmospheric dispersion patterns, landfill and buried pits, and surrounding land uses.

Process Information – product schematics and design, chemicals used and their composition, feedstock and by-product composition, liquid waste management, solid waste management, air pollution control, process changes, storage areas, toxic substance use, and on-site laboratory.

Site Inspections – lagoons, tailings ponds, storage areas, loading/receiving areas, drainage systems, well location, use and condition, wastewater, treatment/disposal, landfill and land farm areas, surface disturbances, underground workings, fuel storage, potential off-site impact, areas transformers, and chemicals/toxic substances.

Historical and Current Operations – development of interview questionnaire for key personnel, process changes, waste management changes, spills and leaks responses, regulatory actions, public complaints.

Regulatory Agency Concerns – compliance studies, air emissions, soil and water contamination concerns, land use compatibility, information from similar sites, public input requirements, contaminant assessment and remediation criteria, approved waste treatment/disposal options.

Phase II: Reconnaissance Testing Program

Health and safety, types of samples, background conditions, analytical procedures, quality assurance, sampling locations, sampling constraints, groundwater, surface water, soils and sediments, sludges, air emissions.

Explanation 2: Does Contaminant Concentration Exceed Assessment Criteria in Figure 4?

Data gathered on soil quality in the site characterization should now be compared with the CCME (1991a) assessment criteria. If contaminant concentrations at the site do not exceed the assessment criteria for the identified contaminant, it is likely that no further action is required. If site levels exceed the assessment criteria, proceed to Explanation 3.

Explanation 3: Identify Intended Land Use

The generic guidelines developed using the soil protocol are intended to protect generic ecological and human receptors that may be exposed to contaminants through a range of exposure pathways associated with four broad land use categories. The land use categories include agricultural, residential/parkland, commercial, and industrial and their definitions follow.

Agricultural land use: lands used for growing crops or producing livestock, and that are agricultural in nature. These also include lands that provide habitat for resident and transitory wildlife and native flora (e.g., transition zones).

Residential/Parkland land use: lands where the primary activity is occupation for residency and recreational purposes. These include lands used as buffer zones between areas of residence, but do not include wildlands, such as national or provincial parks, other than campground areas.

Commercial land use: lands where the primary activity is related to commercial operations, such as the provision of goods and services (e.g., shopping mall) and occupancy is not for residential or manufacturing purposes. These do not include operations where the growing of food is the primary activity (i.e., agricultural).

Industrial land use: lands where the primary activity involves the production, manufacture, construction, or assembly of goods.

The proponent should consider the historical, existing, intended, and potential land use(s) of the site in categorizing the site according to these definitions. Land uses on adjacent sites should also be identified. Groundwater uses (current or likely future uses) (such as raw water for drinking, or crop or livestock watering) should also be identified.

The proponent should also consider land uses at surrounding sites. This is important because the migration of contaminants off-site by soil erosion (by wind or water) or by the movement of surface water or groundwater may contaminate surrounding properties with more susceptible land uses. For example, the off-site migration of soil from a remediated industrial site should not pose any unacceptable risk to a nearby residential site.

Explanation 4: Does Contaminant Concentration Exceed Relevant Background Levels in Figure 4?

Information on relevant background concentrations of metals and certain organic substances is essential for evaluating the applicability of generic soil quality guidelines at any specific contaminated site. In general, background levels of priority substances would be determined at a nearby site that is unaffected by specific contaminant sources (however, the site may be affected by diffuse sources, such as automobile exhaust).

Compare the concentrations of the contaminant of concern with the background levels relevant to the jurisdiction. Relevant background levels will be defined by the jurisdiction and may include, but are not limited to, the CCME interim assessment criteria (CCME 1991a) and provincial background limits.

If relevant site-specific background levels are not available, the proponent may be able to determine background levels, subject to approval by the jurisdictional authority. In general, background concentrations should be determined from an area at the site under investigation, or at a nearby site, sufficiently remote from the source of contamination to be safely presumed to have been unaffected by contaminant release. Areas considered as representative local background must not be subject to off-site impacts of the land under consideration. Similarly, sites containing fill material would compare site concentrations to regional, natural, or indigenous background concentrations, not to the fill concentrations.

If contaminant concentrations do not exceed the relevant background levels, it is likely that no further action is required. Information assembled and decisions taken to this point should, however, be documented.

If contaminant concentrations exceed the relevant background levels, proceed to Explanation 5.

Note that remediation to background concentrations may also be acceptable to the jurisdictional authority. (See Explanation 6.)

Explanation 5: Identify Site-specific Exposure Pathways and Receptors

The soil protocol outlines a method to derive generic guidelines. Several exposure pathways, including direct soil contact, ingestion of soil and of food grown in soil, are used to derive conservative generic guidelines. Generally, guidelines derived using the soil protocol consider the exposure pathways expected for the receptors selected for each land use. In some cases, not all of these exposure pathways will be relevant given the current and likely future use of the site. The proponent may be allowed by the jurisdictional authority to make limited modifications to the generic guidelines in setting the site-specific objectives to reflect the known exposure pathways to the site receptors (Method 2) (Explanations 11 and 15 to 26). The proponent should therefore consider the nature of the contaminants, the receptors (human and ecological), the medium (soil, water, air), and the exposure pathways (direct contact, direct or indirect ingestion, inhalation, etc.) that occur or are likely to occur on the site.

Explanation 6: Cleanup to Background Levels

Ambient background levels of contaminants of concern may be higher than the effects-based generic soil quality guidelines. For instance, background levels in an urban area may be subject to widespread atmospheric deposition of a contaminant. Generally, the NCSRP does not consider it appropriate to remediate contaminated sites to a level below relevant ambient background levels. Therefore the appropriate background level may be used

as the site-specific remediation objective, subject to approval by the jurisdictional authority.

Explanation 7: Is Risk Assessment Appropriate?

When site conditions are outside what was considered in developing the guidelines using the soil protocol, or beyond the limited modifications outlined under Method 2, the site-specific conditions may lead to a recommendation to perform risk assessment as the basis for developing site-specific remediation objectives. Some examples follow:

- when the site is on, or adjacent to, critical habitats that may be at risk, or when there is a large degree of uncertainty associated with the fate and behaviour of the contaminants, such as when the site exhibits unusual characteristics (e.g, fractured bedrock, periodic flooding, permafrost);
- when receptors of concern (such as sensitive populations or rare or endangered species) may be believed to have a high risk potential to the substance(s) of concern;
- when significant data gaps exist related to the behaviour or toxicity of contaminant mixtures or contaminant metabolites at the site; or
- when there are either multiple sources of contamination or exposure pathways not considered in the soil protocol.

At this point, the site-specific conditions may lead to a recommendation to perform risk assessment as the basis for developing site-specific remediation objectives. The proponent/jurisdictional authority may also continue through the process outlined in Figure 4. As additional information about the site-specific conditions is considered, it may lead to a recommendation to perform risk assessment as the basis for developing the site-specific remediation objectives.

Explanation 8: Do CCME Criteria or Guidelines Exist?

Use the appropriate CCME environmental quality guidelines for the soil and/or water uses identified under Explanation 2. If no appropriate generic guidelines are available, three options may be available to the proponent, according to the jurisdictional authority. First, site-specific objectives may be developed using risk assessment (Explanation 12). Second, site-specific objectives may be developed using the CCME soil protocol (Explanation 13). Third, other options within the jurisdiction may be available (e.g., adopting guidelines from other jurisdictions, setting remediation objectives based on background levels, etc.) (see Explanation 14). In any case, the jurisdictional approval for pursuing these options should be sought.

Explanation 9: Do Contaminant Concentrations Exceed Land Use Remediation Guidelines?

Data gathered on soil quality in the site characterization should now be compared with the CCME soil quality guidelines for the appropriate site land use. If contaminant concentrations at the site do not exceed the remediation guideline for the identified contaminant for the particular land use, it is likely that no further action is required. If site levels exceed the remediation guidelines, Method 1 (direct adoption of guidelines) or Method 2 (limited modification of the guidelines) may be used to develop site-specific remediation objectives. If Method 2 (limited modification of generic guidelines) is chosen, the proponent must demonstrate that the conditions outlined in Explanations 15 to 25 apply to the specific site. The proponent may also elect to use or may be required to use Method 3 (risk assessment) by the jurisdictional authority. In some jurisdictions, approval to perform risk assessment may be required by the jurisdictional authority.

Explanation 10: Method 1 – Adopt Generic Guidelines Directly as Site-specific Objectives

The generic guidelines derived using the soil protocol were developed from exposure scenarios that provide a general and conservative level of protection to both human and ecological receptors (see Table 1). Adopting the guidelines directly may be preferred since the exposure scenarios are explicitly stated in the soil protocol and are consistent for all contaminants. As well, the generic guidelines have been derived to provide a generally conservative level of protection for a variety of activities that are likely to occur under the specified land use.

Explanation 11: Method 2 – Modify Generic Guidelines

Certain components of the generic exposure scenarios outlined in the soil protocol for the derivation of generic

guidelines may not be applicable to the specific site. In recognition of this, regulatory authorities may allow the limited modification of the generic guidelines (Method 2). If Method 2 is to be used, further site characterization according to Explanation 15 will likely be required.

Explanation 12: Method 3 – Develop Site-specific Objectives Using Risk Assessment

Use *A Framework for Ecological Risk Assessment: General Guidance* (CCME 1996b.) and/or *Human Health Risk Assessment for Contaminated Sites* (HC 1995), or other appropriate guidance required by the jurisdictional authority.

Explanation 13: Derive Site-Specific Objectives using the Soil Protocol (CCME 1996a)

Site-specific objectives may be developed for the appropriate land use exposure scenario for contaminants for which no effects-based guidelines exist, providing the minimal acceptable data requirements outlined in the soil protocol (CCME 1996a) are followed. Jurisdictional approval for pursuing this option should be sought.

Explanation 14: Consult Other Jurisdictional Options

Other options within the jurisdiction may be available (e.g., adopting guidelines from other jurisdictions, objectives based on background levels, etc.). Jurisdictional approval for pursuing this option should be sought.

Explanation 15: Characterize Site According to Allowable Modifying Parameters

To apply Method 2 more information concerning the allowable modifying parameters will likely be necessary. Data relating to the following factors should be collected and reviewed:

- the presence of and current or likely uses of groundwater;
- the age groups of people who frequent the site;
- the family and species of biota that frequent the site;
- the presence/absence of critical or sensitive habitat;
- for agricultural sites: crop, dairy, or meat production for human consumption;
- for residential/parkland sites: the presence or likely presence of backyard gardens;
- for industrial sites: the surrounding land uses; and
- the presence of basements.

Explanation 16: Modifications to Equation Parameters

The Subcommittee has identified three cases within the soil protocol under which limited modification of the generic guidelines may be permitted through a modification of the equation parameters (see Explanations 17, 18, and 19). These cases were identified on the basis of the relative ease of determining a site-specific value for the parameter.

Note: **While a recalculation may alter the SQG_{HH} (soil quality guidelines considering human health effects), it must be compared with all other allowable modifications for the SQG_{HH} and with the SQG_{E} (soil quality guidelines considering environmental effects) and any of their allowable modifications (Figures 5 and 6). The lowest value will then be selected as the modified soil quality remediation objective.**

Explanation 17: Groundwater Protection

Groundwater uses were identified under Explanations 3 and 15. If groundwater protection is not an issue, this check may be removed and the generic criteria recalculated. **Note that jurisdictional authorization is required if explicit protection of groundwater is not an objective of the site remediation. Note also that this option may forego any future potential uses of groundwater.** An example where such a decision may be appropriate is when the groundwater supply is already contaminated from other sources to an extent where it can no longer sustain a beneficial use.

Groundwater Model

1. This check in the soil protocol deals with the protection of groundwater from soil contamination when developing generic soil quality guidelines.
2. The CCME recognizes that this model is not the only method for calculating a soil guideline that is protective of groundwater; however, a simple model was deemed appropriate for use in developing generic guidelines.
3. Some allowable changes, based on site-specific information (e.g., organic carbon content or groundwater use protection goal) may be made within the check under Method 2.

4. This model does not address other groundwater issues such as transport of contaminants.
5. The proponent should check with the jurisdictional authority whether other models concerning groundwater are also appropriate or required.

Modify Based on Groundwater Use

If groundwater is to be protected, some guidelines modification may still be possible. First, the soil protocol (under the Human Health-based Process – Evaluation of Derived Guidelines Relative to Guidelines for Canadian Drinking Water Quality [CCME 1991a, Section 5]) recognizes that soil containing nonpolar organic substances in contact with groundwater may result in groundwater contamination. If this water is likely to be extracted, it should be of a quality that will not exceed water quality guidelines for that water use. For example, if the groundwater is to be used as raw water for drinking, the residual levels of contaminants in remediated soil should not be allowed to create soil pore water concentrations in excess of the CCME raw water for drinking guideline (CCREM 1987, Chapter 1). The soil protocol considers this in the following equilibrium partitioning equation:

$$Y_a = DF\,[C_{wa}\,(K_d + \theta_m)]$$

where

Y_a = total contaminant concentration in soil in equilibrium with groundwater at the drinking water guideline concentration
DF = generic dilution factor
C_{wa} = the critical concentration in groundwater, set equal to the relevant drinking water guideline
K_d = distribution coefficient
θ_m = mass moisture content

The default value in the soil protocol for C_{wa} is the CCME raw water for drinking guideline. Following permission by the jurisdictional authority, the proponent may substitute an appropriate water quality guideline according to the current or likely future groundwater use. For example, if the groundwater will be used only to water livestock, the CCME livestock watering water quality guideline (CCREM 1987, Chapter 4) for the contaminant of concern, may be used for C_{wa}. (See note in Explanation 16.)

Modify Based on Soil Organic Carbon Content

The characteristics of soils at contaminated sites have the potential to significantly alter the fate and effects of many contaminants. Ranges of organic carbon content and pH encountered in Canadian soil are reported in Alder et al. (1994). While pH, clay type, clay content, and cation exchange capacity of the soil are known to be strong influences, in some cases it was not possible to set a single range that would deal accurately with all types of contaminants. Site managers are strongly urged to read the sections in Alder et al. (1994) appropriate for contaminants of concern at the site.

The presence of atypical but not extreme levels of organic carbon content could affect the mobility and/or bioavailability of contaminants and provide sufficient grounds for a limited modification of the generic criteria. Following the review of Canadian soils by Alder et al. (1994), the Subcommittee nominated an applicable range of soil organic carbon content (f_{oc}), from 0.1 to 17%, for which the soil quality criteria would be widely applicable. The default value for f_{oc} used in the soil protocol (Evaluation of Derived Criteria Relative to Guidelines for Canadian Drinking Water Quality) was 0.1% soil organic carbon. However, if it can be demonstrated that soil organic carbon at the site is between 0.1 and 17%, the actual site value may be substituted in the equation. (See note in Explanation 16.)

If the soil organic carbon content at the site is outside the applicable range of 0.1 to 17% and if mobile organic contaminants are present, a risk assessment may be appropriate.

Modify Based on Location of Contamination

In general, soil organic carbon content decreases with depth. Consequently the greatest attenuation by organic matter is expected to occur at or near the soil surface. When the contamination occurs at depth (e.g., buried waste, leaking underground container, or old landfill site), it is expected that there will be a dramatically different degree of attenuation than would occur at the surface. Therefore, when contamination occurs at depth, the groundwater protection equations should use the soil organic carbon content that occurs at the point of the contamination and beneath (not the surface organic carbon content). (See note in Explanation 16.)

Other Modifications

Actual site values for other factors may differ from the other default values. However, changing other equation parameters is not recommended by the Subcommittee unless a risk assessment is done. The Subcommittee recognizes that more sophisticated groundwater models which use site-specific data are available. However, due to the complexity of the model parameters, the Subcommittee suggests that if the proponent wishes to use such models, jurisdictional consent would be required.

Explanation 18: Direct Human Exposure to Soil

Within the soil protocol, human receptors were considered for all land uses. On agricultural, residential, and parkland sites, children were considered to be the human receptors. On industrial and commercial sites, adults were considered to be the human receptors. In some site-specific circumstances, these may not be the relevant or likely human receptors. Therefore, some limited modification of the guidelines may be allowed by substituting the body weights and the soil ingestion rates of the relevant or likely human receptors at the site. (Reference body weight and soil intake for humans are found in the soil protocol). Note that this modification will require justification to and approval by the jurisdictional authority. (See note in Explanation 16.)

Explanation 19: Direct Soil Contact by Ecological Receptors

Information on the receptors that are (or that would be expected to be) present at a remediated site is important for evaluating the applicability of generic guidelines. The generic guidelines are likely to apply at most sites because of the data acceptability requirements. The soil protocol uses toxicological data on organisms that are native to or raised in Canada, and the preferred calculation uses "weight of evidence" of all acceptable toxicological studies that report no-observed-effect concentration (NOEC) and lowest-observed-effect concentration (LOEC) data.

Remediation objectives, however, may be required at sites that are characterized by the presence of atypical receptors or only a limited diversity of species. Under the rules presented here limited modification of the generic guidelines may be permitted. First, appropriate sampling and ecological classification information must be obtained to assemble a list of the **families** of terrestrial organisms that occur at the site as well as those that occur at a similar but uncontaminated reference site. The reference site list is important, since chronic contamination at a site may have limited the families of biota that could survive the exposure to contamination.

The data set used to derive the generic guidelines for the contaminant of concern may be modified on a site-specific level as detailed in the following administrative rules (1 to 9) if the families of biota are not found to be relevant to either the site under investigation or the reference site.

Decisions regarding the modification of the data set through the elimination of irrelevant data must be supported by detailed rationale. The revised data set must be examined to determine whether the minimum data requirements of the soil protocol are satisfied, to derive a modified environmental soil quality guideline (SQG_E). (See note in Explanation 16.)

Limited Modification Based on Ecological Receptor (Recalculation Procedure)

The modification of the generic soil quality guidelines using an adjusted data set must follow these administrative rules:

1. The onus for demonstrating that species should be excluded from the data set lies with the proponent, not the jurisdictional authority.

2. Toxicological data for species representative of species known or likely to be present at the site (reflective of the intended land use) cannot be excluded from the national data set.

3. For plants, if a member of a family of terrestrial plants occurs or could occur at the site, toxicity data for any plant species of the same family present in the national data set must be retained in the site-specific adjusted data set.

4. For invertebrates, if a member of a family of terrestrial invertebrates occurs or could occur at the site, toxicity data for any species of invertebrate from the same family present in the national data set must be retained in the site-specific adjusted data set.

5. For vertebrates, if a member of a family of terrestrial vertebrates occurs or could occur at the site, toxicity data for any species of vertebrate from the same family

present in the national data set must be retained in the site-specific adjusted data set.

6. Not withstanding points 1 through 5, if data for species within a family are demonstrated to be irrelevant to the site under investigation, they may be deleted if toxicological data are present for one or more additional representative species from the same family in the national data set.

7. Where the data for a species are demonstrated to be irrelevant to the site under investigation but are the only data representative of a family present or potentially present at the site under investigation, the data cannot be deleted from the national data set.

8. The subset of data used under this recalculation procedure must continue to fulfil the CCME's minimum data requirements. If the results of the recalculation procedure cannot meet the soil protocol's minimum data requirements, data for nonresident and/or irrelevant species included in the national database cannot be eliminated.

9. The modified soil quality remediation objective derived through the recalculation procedure must be evaluated by the jurisdictional authority to ensure that it provides the level of protection consistent with the objectives of the soil protocol.

Implicit to the recalculation procedure approach is the requirement that the site-specific toxicological data set used in the recalculation procedure continue to satisfy the minimum requirements of the soil protocol. The information in the data set used to derive the generic criteria has been intensively screened and assessed for its acceptability. For this reason the use of toxicological data derived for the site or the use of supplemental literature data not previously contained in the database used for generic guidelines can be considered for the site in question only as a component of the risk assessment approach and not for recalculation of the generic guidelines. (See note in Explanation 16.)

Explanation 20: Management Checks

Certain management checks in the soil protocol may be reconsidered under specified land uses as described in Explanations 20 to 25 and in Figure 6.

Human Health Process

The guiding principles within the human health procedure of the soil protocol state that

- guidelines should result in no appreciable risk to humans interacting with a remediated site
- guidelines are based on defined representative situations
- guidelines are derived from a consideration of exposure through all relevant pathways
- a critical human receptor is identified for each land use
- guidelines should be reasonable, workable, and useable

The generic soil quality guidelines were derived as conservative benchmarks intended to protect, maintain, or enhance soil quality for given land uses and scenarios. The generic guidelines consider many likely activities for a given land use. The Subcommittee recognizes that some of these scenarios may not occur on the remediated site. Therefore, under Method 2, limited modification of the guidelines may be possible if any of the four generic scenarios outlined in Explanations 21 to 24 will not apply at the remediated site. Note that the limited modifications allowed under Explanations 21 to 24 consist of removing the check from the derivation. Other parameter values within the equations for the human health-based process are not to be altered under Method 2. Other models or other parameter values may be nominated under a site-specific risk assessment, if permitted by the jurisdictional authority. (See note in Explanation 16.)

Explanation 21: Human Food – Backyard Garden

The generic guidelines for residential/parkland land use will not normally be protective of human exposure to local produce consumption. Therefore, this management check is applicable to residential/parkland land uses only where consumption of backyard garden food is, or is likely to be, significant. In such cases, the backyard garden food check may be added to the derivation of the SQG_{HH}. This check in the soil protocol assumes that 10% of produce consumed will be grown on site and that no meat or milk will be produced on site (for a residential setting). (See note in Explanation 16.)

Other parameter values within the equations for the backyard garden check are not to be altered under Method 2. Other models or other parameter values may

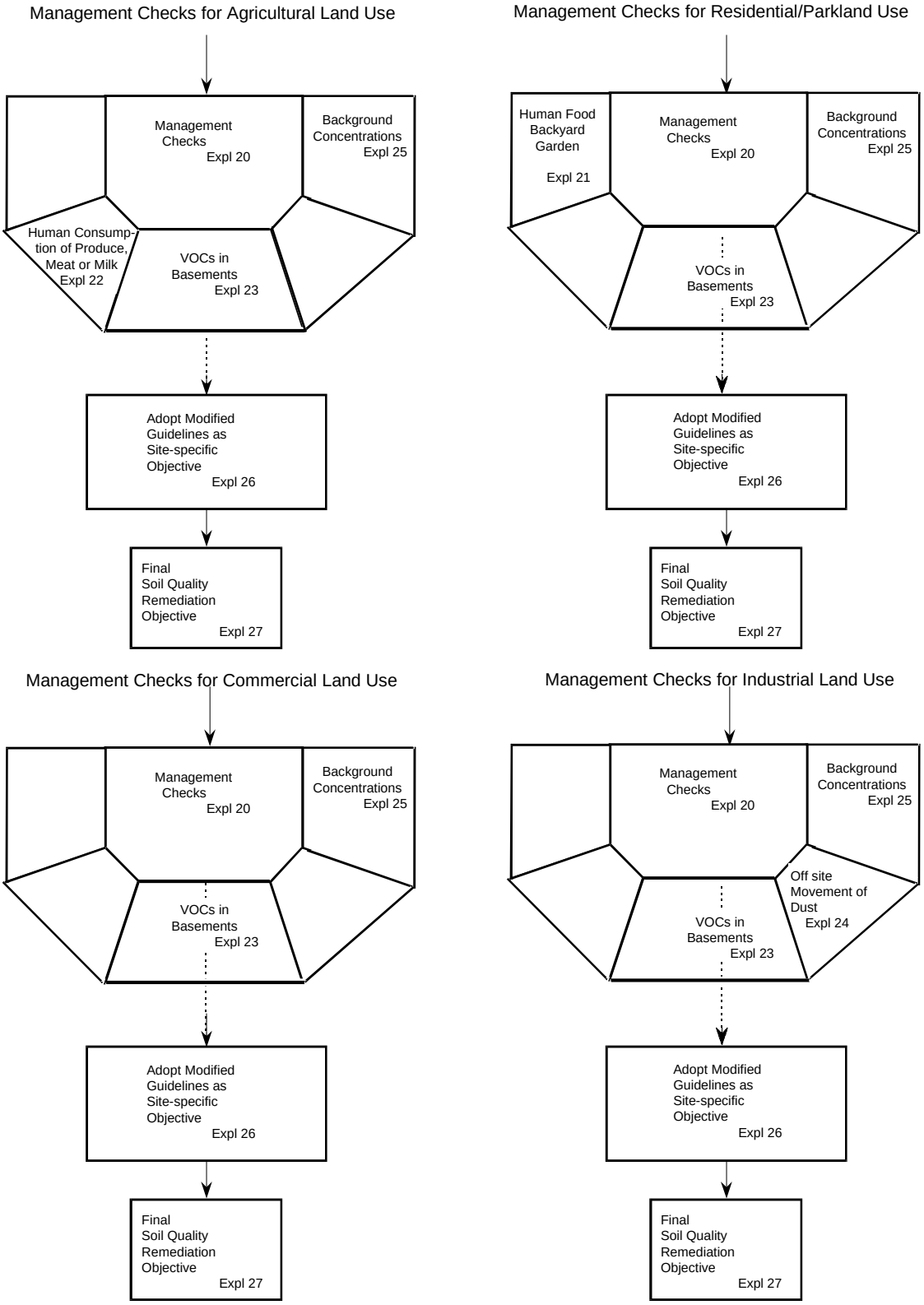

Figure 6. Procedure for management checks for four land uses.

be nominated under a site-specific risk assessment, if permitted by the jurisdictional authority.

Explanation 22: Human Consumption of Produce, Meat, or Milk Produced on Site

This is applicable to the agricultural land use remediation guidelines only, and consists of three components. The generic scenario assumes that 50% of the produce and meat, and 100% of the milk consumed is grown or produced on site. The generic agricultural remediation guidelines will be protective of exposure from/to local produce consumption. Note that if any one of the three is grown on site, the original assumptions should be upheld for that food item. If any of the produce, meat, or milk will be not grown on the remediated site, this check may be removed for that food item. The modified guidelines will be based on an assumption that 100% of the produce, meat, and milk will be grown or produced off site and purchased. The equations to change depend on which food items will not be grown on site and may include

Human daily intake of contaminants from produce:
P_h (percent of produce homegrown) = 0%
P_l, (percent of produce purchased) = 100%

Human daily intake of contaminants from meat:
M_h = (percent of meat home produced) = 0%
M_c = (percent of meat purchased) = 100%

Human daily intake of contaminants from milk:
Mk_h = (percent of milk home produced) = 0%
Mk_c = (percent of milk purchased) = 100%

I_p, I_b, and I_m (CCME 1996a, Appendix B, Section 4.1, Equation 12) will then reflect the fact that either produce, or meat, or milk will not be produced on the remediated site. (See note in Explanation 16.)

Other parameter values within the equations for the human consumption of produce, meat, or milk check are not to be altered under Method 2. Other models or other parameter values may be nominated under a site-specific risk assessment, if permitted by the jurisdictional authority.

Explanation 23: Volatile Organics in Basements

In the derivation of SQG_{HH} for volatile organic contaminants, an uncertainty factor will be applied to address the possible leaking of the volatile organic contaminant through basements (HC 1995). If no basements are present or likely to be present at the remediated site, the uncertainty factor may be removed. (See note in Explanation 16.)

Other parameter values within the volatile-organics-in-basement check are not to be altered. Equations for the other parameter values may be nominated under a site-specific risk assessment if permitted by the jurisdictional authority.

Explanation 24: Off-site Movement of Dust

This is applicable to guidelines intended for industrial land use only. The exposure scenario used for deriving the industrial land use soil quality guidelines accommodates the potential movement of remediated soil from an industrial property to a more sensitive adjacent land use, such as commercial, residential/parkland, or agricultural. However, if the adjacent land use is industrial, this check may not be required. In such cases, the SQG_{HH} need not be compared with C_i (the concentration of contaminant in eroded soil) (CCME 1996a, Appendix E). (See note in Explanation 16.)

Other parameter values within the equations for the off-site movement of dust are not to be altered under Method 2. Other models or other parameter values may be nominated under a site-specific risk assessment if allowed by the jurisdictional authority.

Explanation 25: Modification due to Background Concentrations

Ambient background levels of contaminants of concern may be higher than the effects-based generic soil quality guidelines. For instance, background levels in an urban area may be subject to widespread atmospheric deposition of a contaminant. In terms of relevant background concentrations, the CCME suggests that proponents and jurisdictional authorities make use of local or regional data on background concentrations, but if such information is not available, explicit information on background concentrations at or near the site may be considered. Remediation to a level below relevant ambient background levels is generally not considered to be appropriate. Therefore, if Method 1 (adopting generic criteria directly) is under consideration and if the generic soil quality guideline is below the relevant ambient background level, the relevant background level may be used as the site-specific remediation objective.

If Method 2 (limited modification according to Explanations 17 to 25) has been used and if the modified soil quality guideline is below the relevant ambient background level, that relevant background level may be used as site-specific remediation objective.

Explanation 26: Adopt Modified Guideline as Site-specific Objective

The modified criterion may be used as the site-specific remediation objective. However, note that this guidance manual has dealt with issues of a scientific nature as they relate to the assumptions and calculations of effects-based guidelines under the exposure scenarios defined in the soil protocol. The Subcommittee acknowledges the importance of considering socioeconomic and technical factors in setting site-specific remediation objectives. However, guidance on the consideration of these factors is beyond the scope of the scientific mandate of the Subcommittee.

Explanation 27: Establishment of the Final Soil Quality Remediation Objective

Further consideration of technical feasibility, socioeconomic factors, and risk management strategies may be appropriate in establishing a final soil quality remediation objective. The Subcommittee recommends, however, that all management decisions made during the development of the site management strategy should be fully documented and justified. In this way, the transparency of the process will be maintained and public confidence in the resulting decisions will be enhanced.

3.0 HYPOTHETICAL EXAMPLES

SITE 1

- An orphan site is submitted for NCSRP funding.
- The site is classified as Class 1 (action required) under the National Classification System.
- The range of levels of arsenic (65 to 100 mg/kg dry soil) and cadmium (0.8–15 mg/kg dry soil) on the site exceed the interim assessment criteria in soil (5 and 0.5 ppm, respectively).
- The site is agricultural, used for a mix of activities, including wheat, feed corn, and beef cattle production. Groundwater is used as a drinking water and livestock watering supply.
- The levels of arsenic and cadmium exceed the effects-based remediation guidelines for agricultural land use (hypothetically 14 mg arsenic/kg dry soil and 5 mg cadmium/kg dry soil).*

Decision

Directly adopt the effects-based soil quality remediation guidelines for arsenic and cadmium for agricultural land use as the recommended site-specific remediation objectives.

SITE 2

- An orphan site is submitted for NCSRP funding.
- The site is classified as Class 1 (action required) under the National Classification System.
- The site is residential, located in an area with high soil organic carbon levels (that is, 5% organic carbon content in the soil).
- Site levels of pentachlorophenol (PCP) exceed interim assessment criteria and soil quality remediation guidelines for residential/parkland use, and regional background levels. Studies indicate that the source of contamination is located at the soil surface.
- The site characterization indicated that water from the site is used as a drinking water supply.
- The effects-based guidelines for pentachlorophenol take into account the potential for residual levels of PCP to contribute to soil pore water levels of PCP. However, the high organic carbon level (5%) indicates that greater attenuation can be expected throughout the area than was assumed in the soil protocol.

Decision

The site values of soil organic carbon content, f_{oc}, (5%), replace the default value of 0.1% in:

$$Y_a = DF\,[C_{wa}\,(K_d + \theta_m)]$$

where

* Note: Hypothetical values are used to illustrate the process. However, it is intended that the CCME recommended effects-based soil quality guidelines be used in applying this process to an actual site.

Y_a = total contaminant concentration in soil in equilibrium with pore water at the drinking water guideline concentration
DF = dilution factor
C_{wa} = concentration in the aqueous phase, set at the drinking water guideline
K_d = distribution coefficient, such that $K_d = f_{oc} \times K_{oc}$
f_{oc} = organic carbon content
K_{oc} = sorption coefficient for soil organic carbon, predicted form correlation with the water solubility, or *n*-octanol/water partition coefficient, K_{ow}
θ_m = mass moisture content

Since K_d is much larger than θ_m, the moisture content can be ignored. With all factors except f_{oc} staying constant, the resulting change in groundwater is to increase the human health soil quality guidelines for groundwater protection 50 times, hypothetically from 0.4 mg PCP/kg to 20 mg PCP/kg dry soil (Figure 7). The environmental guideline is hypothetically 1 mg PCP/kg dry soil. Therefore, when the modified human health soil quality guideline (20 mg PCP/kg dry soil) is compared with the environmental soil quality guideline (1 mg PCP/kg dry soil), the lower of the two (1 mg PCP/kg dry soil), is the recommended soil quality remediation objective.

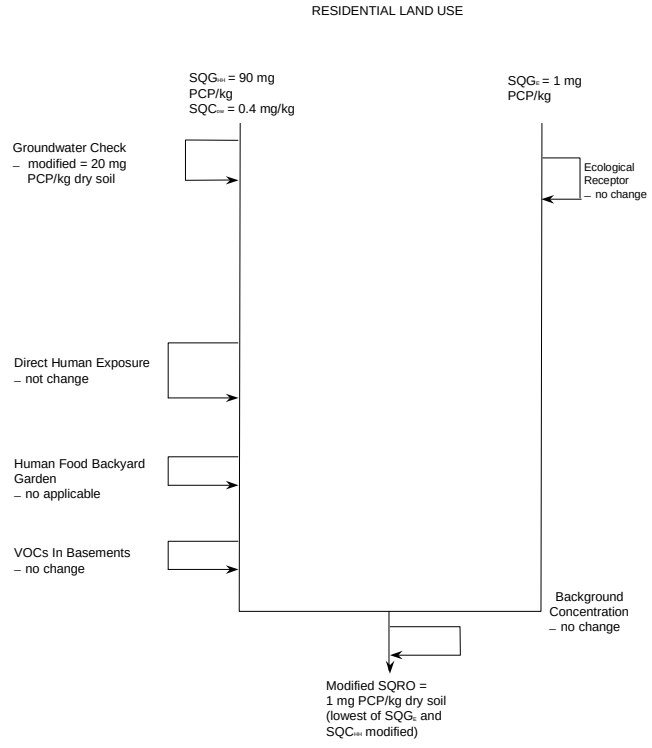

Figure 7. Hypothetical example using Method 2: Modification of generic soil quality guideline within limits to establish recommended soil quality remediation objective.

SITE 3

- An orphan site is submitted for NCSRP funding.
- The site is classified as Class 1 (action required) under the National Classification System.
- The site is industrial with agricultural uses surrounding the property.
- Site is an old storage facility with an unknown chemical mixture in the waste stream.
- The soils contain at least toluene and ethylene glycol at levels that exceed the interim assessment criteria and the remediation guidelines for industrial land uses, as well as a mixture of other contaminants.
- Downstream is a critical habitat for migrating ducks.

Decision

The combination of the presence of a complex mixture of contaminants that were close by and that would likely affect the critical habitat downstream led to the recommendation to perform a risk assessment to establish the site-specific remediation objective.

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Appendix: Checklist for the National Classification System for Contaminated Sites (CCME 1992)

_____ **USER'S GUIDE REVIEWED**

_____ **MINIMUM DATA REQUIREMENTS MET**

_____ Description of site location
_____ Type of contaminants or materials likely to be present at site (and/or description of historical activities)
_____ Approximate size of site and quantity of contaminants
_____ Approximate depth to water table
_____ Geological map or survey information (soil, overburden, and bedrock information)
_____ Annual rainfall data (can be inferred from rainfall map of Canada)
_____ Surface cover information
_____ Proximity to surface water
_____ Topographic information
_____ Flood potential of site
_____ Proximity to drinking water supply
_____ Uses of adjacent water resources
_____ Land use information (on-site and surrounding)

_____ **FACILITY/SITE DESCRIPTION COMPLETED**

_____ **SITE CLASSIFICATION WORKSHEET COMPLETED**

_____ **REFERENCES ATTACHED/CITED**

_____ **EVALUATION FORM COMPLETED**

_____ Detailed Form _____ Short Form

_____ **SCORE SHEET COMPLETED**

_____ **SITE CLASSIFICATION**

Class: _____ 1 _____ 2 _____ 3 _____ N _____I

Score: _____ ± _____
Total Estimated Score Site Identification:

Reference listing:

Canadian Council of Ministers of the Environment. 1996. Guidance manual for developing site-specific soil quality remediation objectives for contaminated sites in Canada. National Contaminated Sites Remediation Program, Canadian Council of Ministers of the Environment, Winnipeg. [Reprinted in Canadian environmental quality guidelines, Chapter 7, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]

For further scientific information, contact:

Environment Canada
Guidelines and Standards Division
351 St. Joseph Blvd.
Hull, QC K1A 0H3
Phone: (819) 953-1550
Facsimile: (819) 953-0461
E-mail: ceqg-rcqe@ec.gc.ca
Internet: http://www.ec.gc.ca

For additional copies, contact:

CCME Documents
c/o Manitoba Statutory Publications
200 Vaughan St.
Winnipeg, MB R3C 1T5
Phone: (204) 945-4664
Facsimile: (204) 945-7172
E-mail: spccme@chc.gov.mb.ca

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