



PROTOCOL 2
FOR CONTAMINATED SITES

Site-Specific Numerical Soil Standards

Prepared pursuant to Section 64 of the
Environmental Management Act

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Date

1.0 Introduction

Section 64 of the *Environmental Management Act* authorizes a Director of Waste Management to establish protocols for the development of numerical standards for contaminated sites within the province.

This protocol sets out procedures for the development of site-specific numerical soil standards (SSSs) for use under the Act. The intent is to allow limited modification of some of the matrix numerical soil standards in the Contaminated Sites Regulation, based on information compiled for a particular site. Ministry-approved SSSs may be used instead of corresponding matrix numerical soil standards for the site for which they were developed to determine if:

- a site is contaminated (as defined in the Act);
- a contaminated site has been satisfactorily remediated; or
- relocation of contaminated soil to a deposit site meets provincial requirements.

Site-specific numerical standards developed for use under the Regulation represent objective, quantitative standards. The ministry will not approve SSSs developed on the basis of qualitative or subjective rationale.

2.0 Overview of the process for developing site-specific numerical soil standards

A four-step process is used to develop and apply site-specific numerical soil standards to manage contaminated sites and relocate contaminated soil.

The first step involves deciding whether numerical standards or risk-based standards will be used for a site. If numerical soil standards are chosen, and sufficient site-specific data are available, then SSSs may be calculated for substances for which there are matrix standards at the site. At this time, with one exception, SSSs may not be derived for substances appearing in Schedules 4 and 6 of the Regulation, which contain generic numerical soil and water quality standards, or Schedule 9, which contains generic numerical sediment criteria. Apart from those methods described in Protocol 10 (Hardness Dependent Site-Specific Freshwater Water Quality Standards for Cadmium and Zinc) methods to derive SSSs for these standards still need to be developed.

The next step is to derive SSSs for those site-specific factors that apply to the site. This protocol explains in detail how to do that. For each substance, the newly derived SSSs for each site-specific factor are tabulated, together with any remaining applicable matrix standards. In effect, this generates a new matrix of standards. The lowest value of the applicable standards in the table becomes the new numerical standard for the substance at the site. This process is shown in Figure 1.

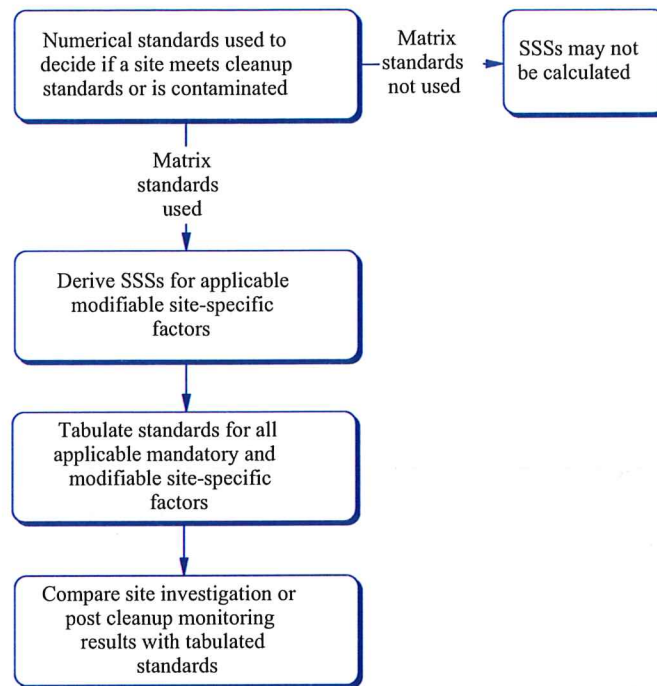


Figure 1. Steps in deriving site-specific numerical soil standards.

Under this protocol, SSSs may be developed by either of the following two approaches:

Method I

This method develops SSSs for a site based on the methods, models, and equations recommended by the Contaminated Sites Soil Taskgroup (CSST) to derive the matrix numerical soil standards in the Regulation. CSST was responsible for extensive standards development work as part of consultations on the Contaminated Sites Regulation.

Details of the standards development procedures of this task group are described in reference 1 (at the end of this protocol).

Method II

In Method II, SSSs are developed for a particular site by using alternate methods, models, and equations instead of those used by CSST to derive matrix numerical soil standards. Site-specific data is used in these new methods, models, and equations to calculate SSSs for the site.

3.0 Site-specific numerical soil standards developed using Method I

3.1 Overview of Method I

In Method I, site-specific numerical soil standards may be developed for a particular site by substituting site-specific data for some of the default values assumed for parameters used by CSST to derive matrix numerical standards. Following data substitution, recalculation produces an SSS for the site.

3.2 Method I – Procedures for Derivation of SSSs Based on CSST Tools

As noted below, SSSs can not always be developed for all types of site-specific factors listed in the matrix standards in the Regulation. Furthermore, the allowable site-specific data substitution is constrained for some parameters. For example, individuals electing to develop a site-specific soil standard to protect groundwater used for a particular site-specific factor must also develop site-specific standards to protect groundwater used for all other site-specific factors that apply at the site.

3.2.1 Method I – Intake of contaminated soil standard

Method I development of SSSs for use instead of this matrix numerical soil standard – intake of contaminated soil – is **not allowed**.

3.2.2 Method I – Groundwater used for drinking water standard

Method I development of SSSs for use instead of this matrix standard – groundwater used for drinking water – is **allowed**.

Under Method I, SSS development is limited to substitution of site-specific data for some of the CSST default values used in equations to derive groundwater protective matrix standards (as shown in section 3.2.9, below).

3.2.3 Method I – Toxicity to soil invertebrates and plants standard

Method I development of SSSs for use instead of this matrix standard – toxicity to soil invertebrates and plants – is **allowed**.

Under Method I, derivation of SSSs to protect against toxicity to soil invertebrates and plants is limited to the procedure shown below. For each substance for which an SSS for toxicity to soil invertebrate and plants is to be developed, use the following steps:

1. Construct an augmented soil invertebrate and plant toxicity data set by incorporating, from relevant peer-reviewed scientific literature, toxicity data for soil invertebrate and plant species that occur onsite. The initial data set is that of the Canadian Council of Ministers of the Environment (CCME) – the data set used by CSST to derive the toxicity to soil invertebrates and plants matrix standards.
2. Substitute the augmented soil invertebrate and plant toxicity data set constructed above for the CSST data set described in section B2.1.2, step 1, found in reference 1.

3. Follow steps 2, 3, and 5 in section B2.1.2 of reference 1 to develop a site-specific toxicity to soil invertebrates and plants soil numerical standard.

The following limitations in developing SSSs to protect against toxicity to soil invertebrates and plants must be observed:

1. Development of toxicity to soil invertebrates and plants SSSs based on site-specific bioassay data compiled for species that occur onsite is **not allowed**. Such data may only be used within the context of an environmental risk assessment for the site.
2. Only peer-reviewed scientific literature toxicity data may be used to augment the CSST toxicity data sets originally used to derive toxicity to soil invertebrates and plants matrix standards. Toxicity data must meet the minimum data requirements shown in sections 7.2 to 7.5 of reference 2 (at the end of this protocol).
3. Toxicity data for only those species that occur onsite may be used to augment CSST data sets. Only those species identified in a ministry-approved species survey for the site in question qualify as species that occur onsite.
4. Application of the empirical exception rule cited in step 4 of section B2.1.2 of reference 1 is **not allowed** in the development of toxicity to soil invertebrates and plants SSSs.

In addition to the documents noted in Section 5 that must be submitted to obtain ministry approval, the following must be submitted, along with a request for ministry approval of any proposed toxicity to soil invertebrates and plants SSS:

- a) a ministry-approved species survey report for the site;
- b) copies of all studies from which peer-reviewed scientific literature toxicity data were abstracted for use in augmenting CSST toxicity data sets; and
- c) documentation of how toxicity data abstracted from peer-reviewed scientific literature comply with CCME minimum data requirements.

3.2.4 Method I – Livestock ingesting soil and fodder standard

Method I development of SSSs for use instead of this matrix standard – livestock ingesting soil and fodder – is **allowed**.

Under Method I, SSS development is limited to substitution of site-specific data for some of the CSST default values as described below. For each substance for which an SSS for livestock ingesting soil and fodder is to be developed, use the following steps:

1. Obtain required site-specific data relating to the parameters listed in Table 1.
2. Substitute the site-specific data obtained to replace CSST default values used in the derivation of livestock ingesting soil and fodder matrix standards, to produce a set of site-specific parameter values.
3. Calculate a proposed livestock ingesting soil and fodder site-specific numerical soil standard using the site-specific parameter values, in conjunction with the equations

and remaining applicable CSST parameter default values shown in section B2.2.2, exhibits 1 and 2, of reference 1.

Table 1. Derivation of SSSs for protection of livestock ingesting soil and fodder: set of CSST parameters for which site-specific data may be substituted

Parameter	Definition (units)	Acceptable Range of Site-Specific Parameter Modification
Bv (as Bv*)	soil to plant transfer coefficient for vegetative tissue [/]	$Bv^* \leq (Bv / 2)$
ED'	duration of exposure [/]	unlimited

The following limitations to the derivation of an SSS for livestock ingesting soil and fodder must be observed:

1. All site-specific data to be used in the calculation of site-specific parameter values must be obtained by methods approved by the ministry (see references 3 and 4 [at the end of this protocol]).
2. Method of calculation and substitution of site-specific estimates of Bv (as Bv*) and ED' are subject to the limitations outlined in reference 3.

In addition to the documents noted in Section 5 that must be submitted to obtain ministry approval, the following must be submitted, along with a request for ministry approval of any proposed SSS to protect livestock ingesting soil and fodder:

- a) site-specific data used in the derivation of the SSSs;
- b) a list of all site-specific parameter values used in deriving the SSSs; and
- c) documentation of how the SSSs comply with the acceptable range of site-specific parameter modifications made.

3.2.5 Method I – Major microbial functional impairment standard

Method I development of SSSs for use instead of this matrix standard – major microbial functional impairment – is **not allowed**.

3.2.6 Method I – Groundwater flow to surface water used by aquatic life standard

Method I development of SSSs for use instead of this matrix standards – groundwater flow to surface water used by aquatic life – is **allowed**.

Under Method I, SSS development is limited to substitution of site-specific data for some CSST default values used in equations to derive groundwater protective matrix standards (as described in section 3.2.9, below).

3.2.7 Method I – Groundwater used for livestock watering standard

Method I development of SSSs for use instead of this matrix standard – groundwater used for livestock watering – is **allowed**.

Under Method 1, SSS development is limited to substitution of site-specific data for some CSST parameter default values used in equations to derive groundwater protective matrix standards (as described in section 3.2.9, below).

3.2.8 Method I – Groundwater Used for Irrigation Watering Standard

Method I development of SSSs for use instead of this matrix standard – groundwater used for irrigation watering – is **allowed**.

Under Method I, SSS development is limited to substitution of site-specific data for some CSST parameter default values used in equations to derive groundwater protective matrix standards (as described in section 3.2.9, below).

3.2.9 Method I – General procedure for developing Method I groundwater protective SSSs

Method I requires back-calculation of groundwater protective site-specific numerical soil standards relevant to approved applicable water quality criteria or guidelines (as described in section B 2.4.2 of reference 1).

For each substance for which a groundwater protective SSS is to be developed, use the following steps:

1. Obtain required site-specific data relating to the parameters listed in Table 2.
2. Substitute the site-specific data obtained in step 1 for corresponding CSST parameter default values to produce a set of site-specific substitute parameter values.
3. Calculate proposed groundwater protective SSSs using the site-specific substitute parameter values, in conjunction with the equations and remaining applicable CSST parameter default values shown in section B 2.4.2, exhibits 3–7, of reference 1. Use 10 times the most current ministry-approved applicable water quality criteria or guideline as the value for the parameter C_w in section B 2.4.2, exhibit 7, of reference 1.
4. If the SSSs are to be used in the formal determination of whether a site is contaminated or not, or to support an application for a Certificate of Compliance for a site, submit the groundwater protective SSSs to the ministry for review and approval.

Table 2. General derivation of SSSs for protection of groundwater uses: set of CSST parameters for which site-specific data may be substituted

Parameter	Definition (units)	Acceptable range for modifying site-specific parameters
X	source dimension length (m)	≥ 5
Y	source dimension width (m)	≥ 5
Z	source dimension depth (m)	≥ 3
x	distance from source to receptor (m)	≥ 10 and ≤ 100
n	porosity of contaminated soil [/]	≥ 0.2 and ≤ 0.4
n_u	water-filled porosity [/]	$n_u \leq n$
n_e	effective porosity [/]	≥ 0.1 and ≤ 0.4
f_{oc}	fraction of organic carbon in soil [/]	≥ 0.001 and ≤ 0.020
V	Darcy velocity in saturated zone (m/yr)	≥ 5 and ≤ 100
d	depth to unconfined groundwater aquifer (m)	≥ 3
d_a	depth of unconfined groundwater aquifer (m)	≥ 5 and ≤ 20
P_b	dry bulk density of soil (g/cm ³)	unlimited
pH _{soil}	pH of soil [/]	≥ 4 and ≤ 9
pH _{groundwater}	pH of groundwater [/]	≥ 4 and ≤ 9
P	precipitation rate (m/yr)	$P \geq (RO + EV)$
(RO + EV)	runoff and evapotranspiration rate (m/yr)	$(RO + EV) \leq P$
$D_{1/2US}$	days when ground surface temperature is below 0° C (days)	≥ 0 and ≤ 365

The following limitations to the general derivation of groundwater protective SSSs must be observed:

1. All site-specific data to be used as site-specific parameter values must be obtained by methods approved by the ministry (reference 4).
2. Several of the general groundwater model variables act as linked parameters in the CSST equations. Consequently, if site-specific data is substituted for the default value used for one of these linked parameters, then site-specific data must also be substituted for the default values used for its corresponding linked variables. Table 3 presents a list of these linked parameters.
3. Equations used in the CSST groundwater model are only applicable to groundwater flow in an *unconfined aquifer*. Derivation of groundwater protective SSSs is **not allowed** if groundwater onsite exists in a *confined aquifer*.
4. Derivation of groundwater protective SSSs is **not allowed** if non-aqueous phase liquids (NAPLs) are present at the site.

Table 3. General derivation of groundwater protective SSSs: set of linked parameters

Linked Parameter Set	Linked parameters
A	X, Y, Z
B	P, (Ro + EV), D _{1/2US}
C	x, n, n _u , n _e , f _{oc} , V, d, d _a , P _b , pH _{soil} , pH _{groundwater}

In addition to documents noted in Section 5 that must be submitted to the ministry, the following must also be submitted when requesting ministry approval of any proposed groundwater protective SSSs:

- a) a list of all site-specific data substitution values used in derivation of the SSSs;
- b) a list of the approved applicable water quality criteria or guideline values used in deriving the SSSs;
- c) documentation of how each SSS complies with approved ministry methods used to obtain site-specific data;
- d) documentation of how each SSS complies with the acceptable range of site-specific parameter modifications made;
- e) documentation of how each SSS complies with data substitution requirements relating to linked parameters; and
- f) a list of all the above components for all other groundwater protective SSSs developed for applicable site-specific uses for the site.

4.0 Site-specific numerical soil standards developed using Method I

4.1 Overview of Method II

In Method II, site-specific numerical soil standards (SSSs) may be developed for a particular site by substituting alternative methods, models, and equations for those used by CSST to derive matrix numerical soil standards. Site-specific data is then used to calculate an SSS for the site.

4.2 Method II – Procedures for derivation of SSSs based on methods, models, and equations other than those used by CSST

As noted below, SSSs can not always be developed for all the types of site-specific factors listed in the matrix standards in the Regulation. Furthermore, the nature of allowable site-specific data substitution is constrained for some parameters.

Individuals electing to develop a site-specific soil standard to protect groundwater used for a particular site-specific factor must also develop site-specific standards to protect groundwater used for all other site-specific factors that apply at the site.

4.2.1 Method II – Intake of contaminated soil standard

Method II development of SSSs for use instead of this matrix standard – intake of contaminated soil – is **not allowed**.

4.2.2 Method II – Groundwater used for drinking water standard

Method II development of SSSs for use instead of this matrix standard – groundwater used for drinking water – is **allowed**. Under Method II, SSS development is limited to method, model or equation substitution (as described in section 4.2.9, below).

4.2.3 Method II – Toxicity to soil invertebrates and plants standard

Method II development of SSSs for use instead of this matrix standard – toxicity to soil invertebrates and plants – is **not allowed**.

4.2.4 Method II – Livestock ingesting soil and fodder standard

Method II development of SSSs for use instead of this matrix standard – livestock ingesting soil and fodder – is **not allowed**.

4.2.5 Method II – Major microbial functional impairment standard

Method II development of SSSs for use instead of this matrix standard – major microbial functional impairment – is **not allowed**.

4.2.6 Method II – Groundwater flow to surface water used by aquatic life standard

Method II development of SSSs for use instead of this matrix standard – groundwater flow to surface water used by aquatic life – is **allowed**. Under Method II, SSS development is limited to method, model, or equation substitution (as described in section 4.2.9, below).

4.2.7 Method II – Groundwater used for livestock watering standard

Method II development of SSSs for use instead of this matrix standard – groundwater used for livestock watering – is **allowed**. Under Method II, SSS development is limited to method, model, or equation substitution (as described in section 4.2.9, below).

4.2.8 Method II – Groundwater used for irrigation watering standard

Method II development of SSSs for use instead of this matrix standard – groundwater used for irrigation watering – is **allowed**. Under Method II, SSS development is limited to method, model, or equation substitution (as described in section 4.2.9, below).

4.2.9 Method II – General procedures for developing Method II groundwater protective SSSs

Method II groundwater protective SSSs may be developed for a particular site by one of the following three sub-methods.

Method IIA:

Development of a groundwater protective SSS for a substance by performing a ministry-approved leachate test on site soil.

This site-specific result is compared with the corresponding generic numerical water quality standard for the substance from Schedule 6. It is not necessary to back-calculate a site-specific soil standard using this approach.

Method IIB:

Development of a groundwater protective SSS for a substance by using site-specific results from a ministry-approved soil leachate test in place of the CSST soil leachate partitioning model estimates for deriving groundwater protective matrix standards.

Method IIC:

Development of a groundwater protective SSS for a substance by using a ministry-approved alternative model in place of the CSST model for deriving groundwater protective matrix standards.

Note: The three Method II sub-methods are mutually exclusive. Responsible person(s) electing to develop groundwater protective standards by Method II must choose one of the above three sub-methods and derive all groundwater protective standards for their site using only that sub-method. Using a combination of Method II sub-methods to develop groundwater protective SSSs for a site is not allowed.

Soil leachate test

Methods IIA and IIB require that a ministry-approved soil leachate test be carried out according to the following procedure:

1. Determine and document the site-specific soil substance total concentration (reference 4).
2. Determine and document the site-specific pH range of site soil (reference 4).
3. Analyze site soil samples according to the procedures detailed in reference 5 (at the end of this protocol).
4. Document the soil leachate test results obtained in step 3 above.

Method IIA procedure

1. Compare the soil leachate test concentration for the substance (obtained in step 4, above) with the corresponding generic numerical water standard in Schedule 6 of the Regulation.
- 2a. If the soil leachate test concentration is less than the applicable water standard for the substance, then simply use the site-specific soil substance total concentration (determined in step 1, above) as the groundwater protective SSS for the site.
- 2b. If the soil leachate test concentration is greater than the applicable water standard for the substance, then use Method IIB to derive an SSS to protect groundwater.

When requesting ministry approval of any groundwater protective SSSs developed under Method IIA, be sure to submit the following documentation (in addition to that noted in section 5.0 of this protocol):

- documentation of compliance with approved ministry methods to obtain site-specific data used to develop the SSSs, including all laboratory data for the soil leachate tests; and
- documentation of compliance with approved ministry methods for deriving all other groundwater protective SSSs developed for applicable site-specific factors pertinent to the site.

Method IIB procedure

1. Compare the soil leachate test concentration (obtained in step 4, above) with the applicable Schedule 6 water standard for the substance in question.
- 2a. If the soil leachate test concentration is greater than the applicable water standard, then use the concentration result obtained in place of the CSST soil leachate partitioning model estimate (as described in section B2.4.2, exhibit 3, of reference 1) – that is, use the concentration result obtained as a site-specific soil leachate estimate.
- 2b. If the soil leachate test concentration is less than the applicable water standard, then use Method IIA to derive an SSS to protect groundwater.
3. Use the soil leachate estimate from step 2a in conjunction with either:
 - a) the remaining CSST parameter default values specified in section B2.4.2, exhibit 8, of reference 1, or
 - b) site-specific data substituted for applicable exhibit 8 CSST parameter default values (in accordance with section 3.2.9 above),

to develop a groundwater protective SSS in accordance with the equations in section B2.4.2, exhibits 4–7 of reference 1.

When requesting ministry approval of any groundwater protective SSSs developed under Method IIB, be sure to submit the following documentation (in addition to that noted in section 5.0 of this protocol):

- documentation of compliance with approved ministry methods to obtain site-specific data used to develop the SSSs, including all laboratory data for the soil leachate tests;
- documentation of compliance with approved ministry methods for deriving all other groundwater protective SSSs developed for applicable site-specific factors pertinent to the site; and
- if the groundwater protective SSSs were developed in accordance with step 3b, all documents required under section 3.2.9 of this protocol.

Method IIC procedure

In Method IIC, groundwater protective SSSs are developed based on the use of models or equations other than the CSST default derivation models or equations. This requires that:

- a) only scientifically peer-reviewed alternative models or equations be substituted for CSST models or equations;
- b) peer-reviewed alternate models or equations must be transparent – that is, accompanied with complete descriptions of the parameters used and the mathematical relationships assumed to exist between parameters;
- c) substitution of non-transparent proprietary models or equations to derive groundwater protective SSSs **not be allowed**; and
- d) to the maximum extent possible, site-specific data (not assumed parameter default values) be used in the alternative models or equations for developing the groundwater protective SSSs.

When requesting ministry approval of any groundwater protective SSSs developed under Method IIC, be sure to submit the following documentation (in addition to that noted in section 5.0 of this protocol):

- a) documentation of compliance with the requirement for the use of transparent, scientifically peer-reviewed alternative models or equations, including copies of all relevant scientific papers, journal articles, reports, communications, or assessments;
- b) documentation of compliance with approved ministry methods to obtain site-specific data used in the development of the SSSs;
- c) a written request by the responsible persons for the site for the review and approval of all alternative models or equations used and all alternative parameter default values used; and
- d) components, as listed above, for all other groundwater protective SSSs developed for applicable site-specific factors pertinent to the site.

5.0 General requirements for submission of site-specific numerical soil standards for review and approval by the ministry

To obtain ministry approval of site-specific standards, the following must be submitted (in addition to those data submission requirements prescribed elsewhere in this protocol):

- a) complete documentation of the calculation and derivation of all site-specific soil numerical standards proposed for use at the site; and
- b) a formal application for the review and approval of all site-specific soil numerical standards proposed for use at the site.

6.0 References

1. BC Environment. (1996). Overview of CSST Procedures for the Derivation of Soil Quality Matrix Standards for Contaminated Sites. Victoria, BC. January 31, 1996.
2. Canadian Council of Ministers of the Environment. (1996). A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines. Winnipeg, MB. March 1996.
3. BC Environment. (1998). Procedure for Calculation of Bv* and ED' for Use in the Development of Livestock Protective Site-Specific Numerical Soil Standards. Victoria, BC. February 1998.
4. BC Environment. (1997). Guidance on Contaminated Sites: Site Characterization and Confirmation Testing. Victoria, BC. February 1997.
5. BC Environment. (pending). Soil Leachate Test Methods for the Derivation of Site-specific Standards. Victoria, BC.

For more information, contact the Environmental Management Branch at site@gov.bc.ca.