Ministry of Environment and Climate Change Strategy

PROTOCOL 2
FOR CONTAMINATED SITES

Site-Specific Numerical Soil Standards

Version 2.2

Prepared pursuant to Section 64 of the
Environmental Management Act

Approved: Douglas Hill, Director of Waste Management — April 30, 2024, Date

Effective Date: May 1, 2024

1.0 Definitions

The following words, acronyms and expressions used in this document are defined in the Environmental Management Act (EMA), the Contaminated Sites Regulation (CSR) and ministry Procedure 8, “Definitions and Acronyms for Contaminated Sites”:

aquatic life water use	ministry
contaminated site	mobile nonaqueous phase liquid
Regulation	nonaqueous phase liquid
drinking water use	numerical water standards
EPH_{s10-19}	point of compliance
EPH_{s19-32}	qualified professional
irrigation water use	receiving environment
livestock water use	site-specific numerical standard
matrix numerical soil standard	VH_{s6-10}

2.0 Introduction

This protocol sets out procedures for deriving site-specific numerical soil standards (SSSs) for use on contaminated sites under the CSR.

SSSs derived under this protocol replace the matrix numerical soil standards prescribed in Schedule 3.1 Part 1 of the CSR for the site-specific factors protective of groundwater use. SSSs may be derived for all groundwater uses for which matrix numerical soil standards are prescribed.

Matrix numerical soil standards for the site-specific factors “Intake of contaminated soil”, “Toxicity to soil invertebrates and plants”, “Livestock ingesting soil and fodder”, and “Major microbial functional impairment” cannot be substituted.

SSSs derived under this protocol do not require a Director’s decision except as described in Section 7.0.

SSSs may be used to determine:

- if the site is a contaminated site under section 11 (2) of the CSR;
- whether the site has been satisfactorily remediated under section 17 (2) (a); or

- whether soil is waste for the purposes of section 41 of the CSR.

Technical guidance supporting the application of this protocol is provided in Technical Guidance 24 “Site-Specific Numerical Soil Standards Model Parameters”.

> The numerical soil standard on a site is selected as the lowest value of:
> - the derived SSS(s) for the applicable site-specific factors protective of groundwater use;
> - the mandatory matrix numerical soil standards for the site-specific factors “Intake of contaminated soil” and “Toxicity to soil invertebrates and plants”; or
> - the matrix numerical soil standard(s) for other applicable site-specific factors.

3.0 Overview

Two methods for deriving site-specific soil standards are described in this protocol:

1. Modified Groundwater Protection Model (GPM) method; and
2. Leachate Test method.

Qualified professionals can choose to use either the Modified GPM method or the Leachate Test method to derive a SSS for a substance at a site. If both methods are applied to derive a SSS for a substance, the higher of the concentrations may be applied as the SSS for the specific substance.

If a SSS derived for a substance at a site is lower than or equal to the corresponding matrix numerical soil standard, the matrix numerical soil standard applies.

The flowchart in Figure 1 is provided to assist with navigation of the SSS process.

4.0 Precluding conditions

SSSs cannot be derived for petroleum hydrocarbon substances and potential co-contaminants on sites where mobile nonaqueous phase liquids (NAPL) with potential to migrate are present as defined in Protocol 16 “Determining the Presence and Mobility of Nonaqueous Phase Liquids and Odorous Substances”.

5.0 SSSs derived using the Modified GPM method

SSSs can be derived using the ministry's Groundwater Protection Model (GPM) found in Technical Guidance 13.

The GPM is an analytical fate and transport model that is used to derive the matrix numerical soil standards in Schedule 3.1 Part 1 of the CSR for the site-specific factors protective of groundwater use. The matrix standards are derived using default model parameters in the GPM. SSSs are derived using site-specific model parameters in the GPM that have been obtained from site investigations conducted at the site of interest.

The GPM calculates a substance concentration in soil, Cs, that when partitioned into water and transported along a groundwater flow path will result in the concentration, Cx, in groundwater at the point of compliance, taking into account the following model processes:

- soil-leachate partitioning;
- unsaturated transport;
- mixing at groundwater table; and
- saturated transport to the point of compliance.

A detailed description of the GPM and the default model parameters used to derive the matrix numerical soil standards can be found in Protocol 28 "Generic Numerical Standards", Chapter 4, Derivation of Soil to Groundwater Protection Matrix Soil Quality Standards.

The Modified GPM method may only be used for the shallowest unconfined aquifer.

5.1 Model parameters

SSSs under the Modified GPM method are derived by substituting modified parameter values for the default model parameters in the GPM. Depending on parameter sensitivity, four different approaches can be applied to determine how to modify the GPM parameters:

- default parameters;
- regional look-up parameters;
- literature parameters; and
- site-specific parameters.

The approach that may be applied for each model parameter is listed in Table 1. All model parameters, except for the physical/chemical properties, can be varied when deriving a SSS for a substance at a site following the criteria listed below. For pH sensitive substances, site-specific values for pH of soil are required. Further, for pentachlorophenol [PCP], site-specific values for pH of water are required when deriving SSSs protective of aquatic life. For water hardness sensitive substances, site-specific values for water hardness of the receiving environment are required when deriving SSSs protective of aquatic life. If a parameter is not modified, the default parameter value will apply. For infiltration, regional values can be obtained from the look-up table/figure provided in Appendix 1. If using alternative methods to determine site-specific infiltration, a Director's decision is required, see section 7.0. For porosity and dry bulk density, either literature or site-specific parameter values can be used as substitutes for the default parameters. Physical/chemical properties can only be modified through a Director's decision, see section 5.1.4.

Table 1. Determining site-specific model parameters

Category	Parameter	Symbol	Default	Look-up table	Literature	Site-specific
Source dimensions	Source length	X	X			X
	Source width	Y	X			X
	Source depth	Z	X			X
Infiltration	Infiltration	I	X	X		Director's decision
Hydrogeology	Total porosity	N	X		X	X
	Water filled porosity	n_w	X			X
	Effective porosity	n_e	X		X	X
	Dry bulk density	ρ_b	X		X	X
	Fraction of organic carbon	f_{oc}	X			X
	pH of soil	pH_{soil}	X[1]			X
	pH of groundwater	pH_{water}	X[2]			X
	Water hardness	H	X[3]			X
	Hydraulic conductivity	K	X			X
	Hydraulic gradient	I	X			X
	Aquifer thickness	d_a	X			X
	Depth to water table	D	X			X
	Distance to point of compliance	X	X			X
Physical/ Chemical	Half-life	$t_{1/2s}$	X			Director's decision
	Distribution coefficient	K_{oc}/K_d	X			Director's decision
	Henry's Law constant	H'	X			Director's decision
	Solubility	S	X			Director's decision
	Number of days when ground surface < 0° C	D_{fr}	X			Director's decision

[1]Site-specific values for pH_{soil} are required when deriving SSSs for pH-sensitive substances.
[2]Site-specific values for pH_{water} are required when deriving SSSs for pentachlorophenol [PCP] protective of aquatic life.
[3]Site-specific values for water hardness of the receiving environment are required when deriving SSSs protective of aquatic life for hardness-sensitive substances.

Site-specific parameter values can be modified within the acceptable parameter ranges included in Table 2. If a qualified professional wishes to adjust a parameter outside the acceptable range, a Director's decision is required as described in Section 7.0.

Table 2. Acceptable ranges for site-specific model parameters

Category	Parameter	Symbol	Unit	Default value	Acceptable range
Source dimensions	Source length	X	m	10	≥ 5
	Source width	Y	m	30	≥ 5
	Source depth	Z	m	3	≥ 3
Infiltration	Infiltration	I	m/yr	0.55	≥ 0.08
Hydrogeology	Total porosity	n	-	0.36	≥ 0.2 and ≤ 0.4
	Water filled porosity	n_w	-	0.119	$n_w \leq n$
	Effective porosity	n_e	-	0.25	≥ 0.1 and ≤ 0.4
	Dry bulk density	ρ_b	g/cm^3	1.7	≤ 1.9
	Fraction of organic carbon	f_{oc}	-	0.005	≥ 0.001 and ≤ 0.050
	pH of soil	pH_{soil}	-	6.5	≥ 5 and ≤ 9
	pH of groundwater	pH_{water}	-	6.5	≥ 5 and ≤ 9
	Water hardness	H	mg/L	200	≥ 0 and ≤ 500
	Hydraulic conductivity	K	m/s	3E-5	-
	Hydraulic gradient	i	-	0.008	-
	Average linear velocity	v	m/yr	30.3	≥ 5 and ≤ 250
	Aquifer thickness	d_a	m	5	≥ 5 and ≤ 20
	Depth to water table	d	m	3	≥ 1
	Distance to point of compliance	x	m	10	≥ 10 and ≤ 500
	Vertical distance between base of source and water table	b	m	0	≤ 10

Site-specific parameter values must be determined using data from field or laboratory methods approved or referenced by the ministry using the criteria below. Technical guidance for determining site-specific model parameters is provided in Technical Guidance 24, along with a model sensitivity analysis to assist qualified professionals in running the GPM.

5.1.1 Source dimensions

Under Protocol 2, a contaminant source is defined based on its ability to impact the groundwater quality at a site.

The following methodologies must be used for modifying the default source dimensions used in the GPM for various sources. A flowchart is provided in Figure 2 to assist with determining source dimensions.

Petroleum hydrocarbon sources

A petroleum hydrocarbon source is defined as a mixture of hydrocarbon compounds of petroleum origin. Under Protocol 2, a petroleum hydrocarbon source is defined by the greater of the horizontal and vertical extent of either:

- NAPL presence, as defined in Protocol 16; or
- soil concentrations of:
    - VH_{s6-10} greater than 100 µg/g; or
    - EPH_{s10-19} greater than 1000 µg/g; or
    - EPH_{s19-32} greater than 1000 µg/g.

Under Protocol 2, a petroleum hydrocarbon source is considered not present at a site, if all the following requirements are met:

1. the potential contaminant source is demonstrated to be a mixture of petroleum hydrocarbon compounds that has been present for a minimum of:
    - five years for an unpaved site, or
    - ten years for a paved site;
2. no NAPL is identified on the site;
3. the site has been characterized in accordance with Technical Guidance 10 “Guidance for a Stage 1 Preliminary Site Investigation” and Technical Guidance 11 “Guidance for a Stage 2 Preliminary Site Investigation and Detailed Site Investigation” and the maximum soil concentration of:
    - VH_{s6-10} is less than or equal to 100 µg/g; and
    - EPH_{s10-19} is less than or equal to 1000 µg/g; and
    - EPH_{s19-32} is less than or equal to 1000 µg/g;
4. groundwater has been sampled at a minimum annually for the previous two years directly below and immediately downgradient of the potential hydrocarbon source; and individual substance concentrations are less than or equal to the applicable numerical water use standard listed in Schedule 3.2 of the CSR.

On sites where all four requirements are met, the matrix numerical soil standards for petroleum hydrocarbon substances for the site-specific factors protective of groundwater use do not apply. The mandatory matrix standards and other applicable matrix standards still apply.

On sites where the first three requirements are met, but substance concentrations in groundwater exceed applicable numerical water use standards, the default site-specific source dimensions (X=10 m, Y=30 m, Z=3 m) must be used, but the

parameter “depth to water table” may be modified as described in Section 5.1.3 below.

Inorganic sources and organic (non-petroleum hydrocarbon) sources
Under Protocol 2, the horizontal and vertical dimensions of an inorganic source or a non-petroleum hydrocarbon organic source are defined based on substance concentrations in soil that are:

- greater than the applicable soil standards listed in Schedule 3.1 Part 1 of the CSR; or
- greater than a SSS derived under the Modified GPM method by substituting one or more of the following model parameters in the GPM: infiltration, total porosity, water filled porosity, effective porosity, dry bulk density, fraction of organic carbon, pH of soil, pH of groundwater, hydraulic conductivity, hydraulic gradient, aquifer thickness; or
- greater than a substance concentration in background soil established under Protocol 4 “Establishing Background Concentrations in Soil”.

5.1.2 Infiltration
Infiltration is calculated based on the precipitation rate, P, and the runoff and evapotranspiration rate, RO+EV. The default parameter value of 550 mm/year can be modified using regional data found in the look-up table/figure in Appendix 1.

The infiltration rate cannot be lower than 80 mm/year.

5.1.3 Hydrogeology
Site-specific data from groundwater investigation is required to modify the hydrogeological parameters in the GPM. All modified parameter values must be from the same hydrogeologic unit. Where multiple units may be present, parameter values must be based on the unit most representative and of concern for contaminant flow and transport at the site.

Hydrogeological parameters with a lower relative sensitivity in the GPM can be modified using either a literature value or site-specific data. These parameters include:

- Total porosity;
- Water filled porosity (default or site-specific only);
- Effective porosity;
- Dry bulk density;
- pH of groundwater; and
- Aquifer thickness (default or site-specific only).

Hydrogeological parameters with a higher relative sensitivity in the GPM can only be modified using site-specific data. These parameters include:

- Fraction of organic carbon;
- Hydraulic conductivity;
- Hydraulic gradient;
- pH of soil;
- Depth to water table ; and
- Distance to point of compliance.

Site-specific data is required to determine the water hardness of the receiving environment.

“Depth to water table” is a sensitive model parameter for organic substances that degrade in the unsaturated zone. The “depth to water table” can only be modified from its default value of 3 m, when site-specific parameters are available for source dimensions following criteria listed in Section 5.1.1.

“Distance to point of compliance” can only be modified from its default parameter value of 10 m when site-specific parameters are available for source dimensions following criteria listed in Section 5.1.1. The “distance to point of compliance” can be modified from its default value based on the following criteria:

- For the site-specific factors “Groundwater used for drinking water”, “Groundwater used for livestock watering” and “Groundwater used for irrigation”, the “distance to point of compliance” can be modified to the lateral distance between the source and the downgradient property boundary provided substance concentrations in site groundwater meet the applicable water use standards in Schedule 3.2 of the CSR.
- For the site-specific factor “Groundwater flow to surface water used by aquatic life”, the “distance to point of compliance” can be modified to the lateral distance between the source and 10 m from the high water mark of the downgradient aquatic receiving environment provided substance concentrations in groundwater meet the applicable water use standards in Schedule 3.2 of the CSR at the downgradient property boundary.

The “distance to point of compliance” cannot be modified from its default value of 10 m when deriving SSS(s) for purposes of soil relocation.

The flowchart in Figure 2 provides guidance for evaluating the "depth to water table" and "distance to point of compliance".

5.1.4 Physical/chemical properties

The GPM uses ministry determined parameter values for the following physical/ chemical properties: half-life, distribution coefficient, Henry's Law constant and solubility. The physical/chemical properties cannot be modified under the Modified GPM method. If alternative, scientifically defensible physical/chemical properties are available, a qualified professional can apply to use site-specific values in a Director's decision as described in Section 7.0. To modify the half-life, the model parameter for number of days frozen, D_{fr}, must be modified based on site-specific conditions, if different than the default value of 0 days.

5.2 Documentation

The following documentation must be provided in support of a SSS derivation using the Modified GPM method:

- Description of site-specific parameters used in the GPM and the methodology and supporting data used to determine the parameter values;
- Print-out of model documentation;
- Comparison of derived SSSs with applicable matrix numerical soil standards to determine the applicable numerical soil standards; and
- A written signed statement prepared by a qualified professional confirming:
  - they have demonstrable experience in hydrogeological investigation and assessment of contaminated sites, and
  - that the SSS(s) for which documentation is provided have been developed in accordance with this protocol.

6.0 SSSs derived using the Leachate Test method

SSSs can also be derived using the Leachate Test method and the results of leachate testing carried out in accordance with methods and procedures set out in Protocol 27 "Soil Leaching Assessment for Use in Derivation of Site-Specific Numerical Soil Standards at Contaminated Sites".

The flowchart in Figure 3 is provided to assist with navigation of the Leachate Test method.

Under this method, SSSs are determined by comparing substance concentrations in soil leachate to either the applicable numerical water use standard listed in Schedule 3.2 of the CSR or the modelled leachate concentration, C_L, determined using the ministry's GPM. The modelled leachate concentration, C_L, is calculated using the "SSS Model Type" in the GPM and the applicable numerical water use standard at the point of compliance. Either the default model parameters or site-specific model parameters, as described in Section 5.1, can be used for this purpose.

The maximum concentration measured for a substance in soil, as prescribed in Protocol 27, can be used as the applicable SSS if one of the following applies:

1. the substance concentration in soil leachate is less than or equal to the applicable numerical water use standard listed in Schedule 3.2 of the CSR; or
2. the substance concentration in soil leachate is less than or equal to the modelled concentration in leachate, $C_{L,default}$, derived using the GPM with default parameters; or
3. the substance concentration in soil leachate is less than or equal to the modelled concentration in leachate, $C_{L,site\text{-}specific}$, derived using the Modified GPM method with site-specific parameters determined as described under Section 5.1.

> The modelled leachate concentration, $C_{L,default}$, derived using default parameters in the GPM (option 2), results in a $C_{L,default}$ that is a minimum of 3.3 times the applicable numerical water use standard (greater relief is obtained for substances that degrade). This is due to the GPM running backwards where mixing at the groundwater table results in a default dilution factor, DF, of 3.3.
>
> Therefore, instead of running the GPM under option 2, the maximum substance concentration measured in soil can be used as the applicable SSS if the measured substance concentration in the soil leachate is less than or equal to 3.3 times the applicable water use standard listed in Schedule 3.2 of the CSR.

A SSS cannot be derived under the Leachate Test method when the measured concentration of a substance in soil leachate is greater than the modelled concentration of that substance in leachate obtained using the GPM under either the default or modified (site-specific) method.

6.1 Documentation

The following documentation must be submitted for a SSS derived using the Leachate Test method:

- Documentation required under Protocol 27 for the leachate test performed;
- Comparison of substance concentrations in leachate with either the applicable numerical water use standard or the modelled leachate concentration, C_L, using the GPM;
- If using site-specific parameters to model the leachate concentration, description of site-specific parameters, methodology for determining parameter values, and print-out of model documentation;
- Comparison of derived SSS(s) with applicable matrix numerical soil standards to determine the applicable numerical soil standards; and
- A written signed statement prepared by a qualified professional confirming:
  - they have demonstrable experience in hydrogeological investigation and assessment of contaminated sites, and
  - that the SSS(s) for which documentation is provided have been developed in accordance with Protocol 27 and this protocol.

7.0 SSSs derived using Director's decision

On sites where the Modified GPM method or Leachate Test method do not provide sufficient relief in deriving SSSs, site owners and operators may request a Director to make a site-specific decision of SSSs using alternative methods.

Examples of alternative methods that would be considered by the Director for use in deriving a SSS where demonstrated to be scientifically defensible include:

- Use of site-specific model parameters outside the parameter ranges provided for use under the Modified GPM method (Table 2).
- Use of site-specific model parameters instead of default parameters that cannot be modified under the Modified GPM method (Table 1).

7.1 Documentation

A request for a Director's decision of SSSs must be accompanied by a completed Contaminated Sites Services Application form and a supporting technical report prepared by a qualified professional. Depending on the alternative method applied, the technical report must include documentation of site-specific parameters used in the Modified GPM method, including description of the methodology to obtain site-specific data used in the development of the SSSs.

For more information, please direct inquiries to site@gov.bc.ca.

Revision history

Approved Date	Effective Date	Document Version	Notes
November 1, 2017	November 1,	2.1	Updated for CSR Stage 10 amendment
April 30, 2024	May 1, 2024	2.2	Updated for CSR Stage 14 amendment

Figure 1 Protocol 2 process

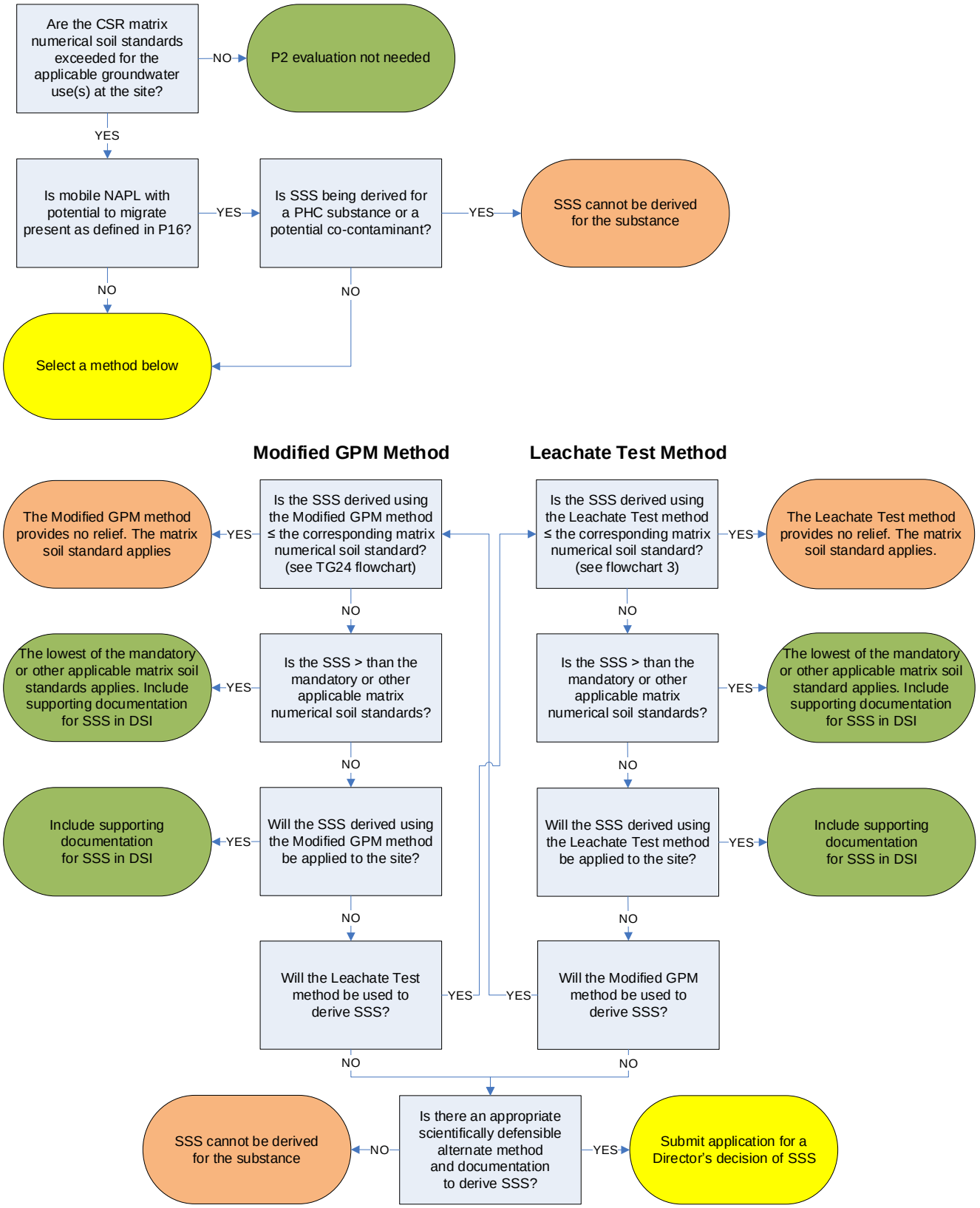


Figure 2 Determining source dimensions, depth to water table, and distance to point of compliance

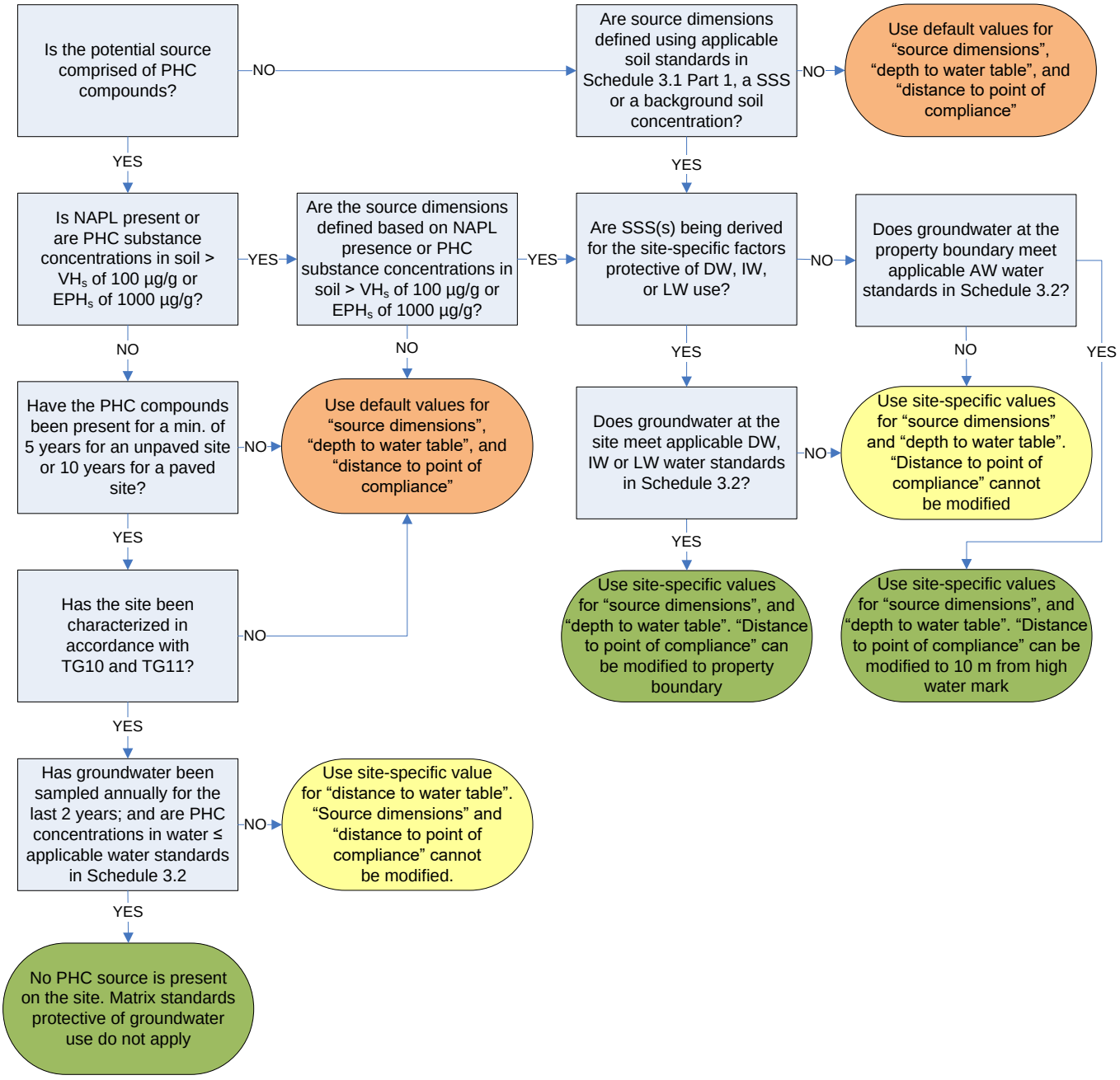
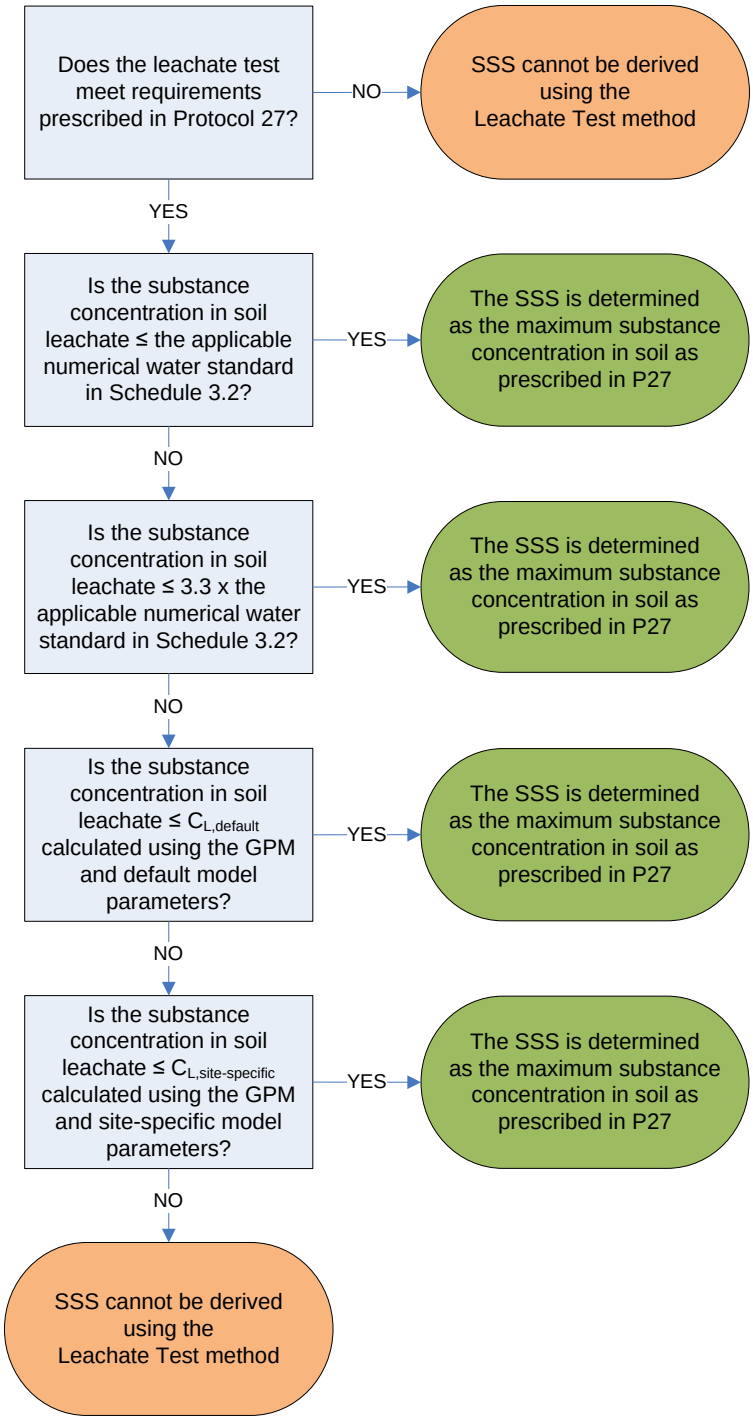


Figure 3 Deriving SSS using the Leachate Test method



Appendix 1 – Regional infiltration data

Table 1 Infiltration data

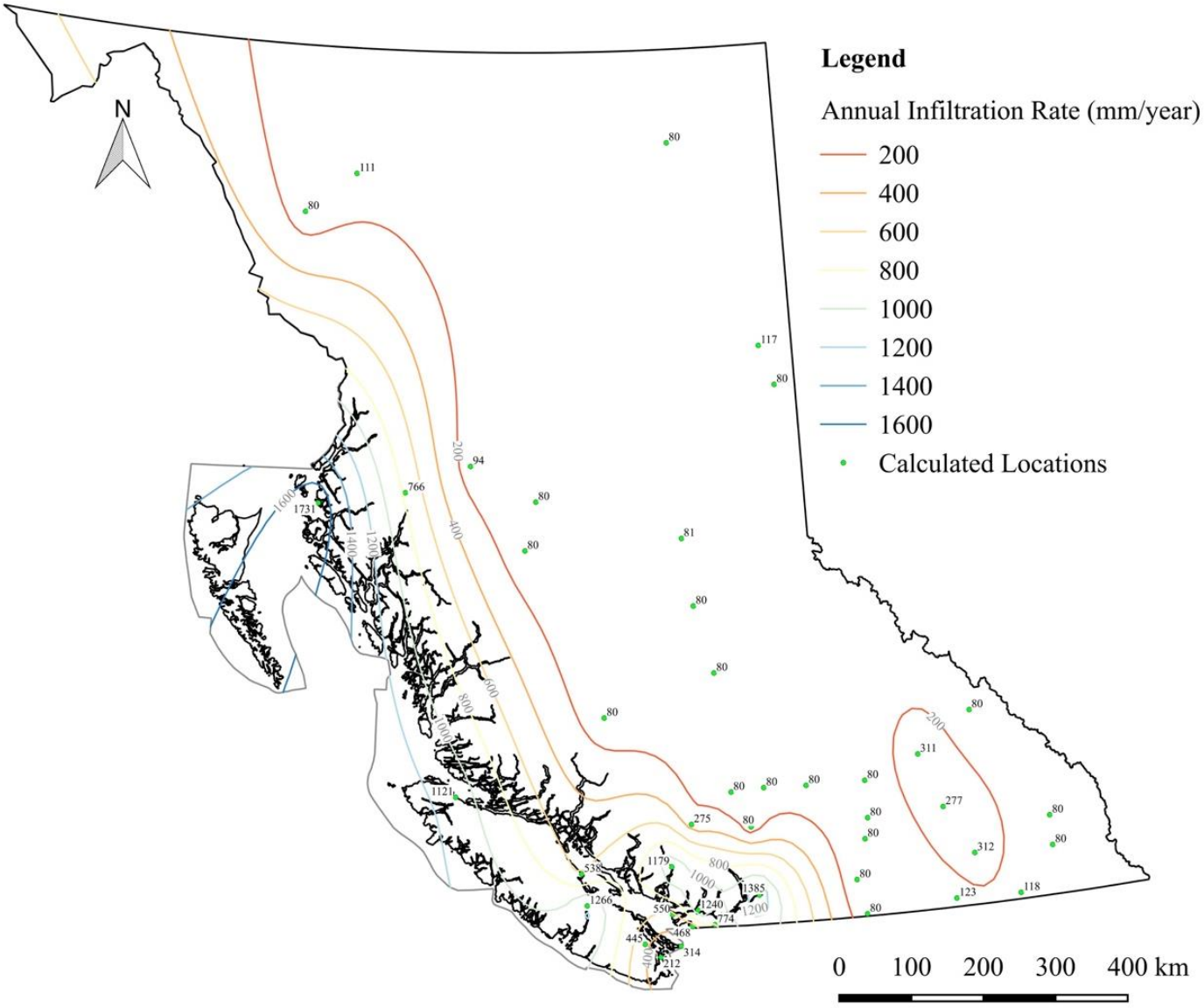
Location No.	Station Name	Latitude	Longitude	Precipitation (mm)	ET + RO (mm)	Infiltration Rate (mm)
01	Abbotsford	49.03	-122.3807	1538	764	774
02	Ashcroft	50.71	-121.28	209	559	80*
03	Burns Lake	54.38	-125.7667	437	434	80*
04	Comox	49.72	-124.9032	1154	616	538
05	Cranbrook	49.62	-115.7859	385	548	80*
06	Creston	49.08	-116.5113	662	544	118
07	Dawson Creek	55.73	-120.4528	453	439	80*
08	Dease Lake	58.43	-130.01	445	334	111
09	Fort Nelson	58.83	-122.5893	452	385	80*
10	Fort St John	56.23	-120.7394	445	328	117
11	Golden	51.4357	-117.0571	467	484	80*
12	Hope	49.37	-121.5	2342	957	1385
13	Kamloops	50.7	-120.4418	387	563	80*
14	Kelowna	49.97	-119.38	387	586	80*
15	Lillooet	50.68	-121.93	349	567	80*
16	Lytton	50.23	-121.5767	431	591	80*
17	Nakusp	50.27	-117.8011	840	563	277
18	Nelson	49.65	-117.2937	924	612	312
19	North Cowichan	48.82	-123.72	1153	708	445
20	Ootsa Lake Skins Lake Spillway	53.77	-126	417	533	80*
21	Osoyoos	49.03	-119.46523	323	600	80*
22	Pemberton	50.3	-122.739	933	658	275
23	Penticton	49.47	-119.6052	346	574	80*
24	Pitt Meadows	49.22	-122.6904	2155	915	1240
25	Port Alberni	49.32	-124.8069	2199	933	1266
26	Port Hardy	50.68	-127.37	1908	787	1121
27	Prince George	53.88	-122.6739	595	514	81
28	Prince Rupert	54.29	-130.44	2619	888	1731
29	Quesnel	53.03	-122.4932	536	547	80*
30	Revelstoke	50.96	-118.18	950	640	311
31	Salmon Arm	50.7	-119.28	653	614	80*
32	Saturna Island	48.78	-123.04	812	498	314
33	Skookumchuck	49.9943	-115.7611	455	599	80*
34	Smithers	54.82	-127.1835	509	415	94

Location No.	Station Name	Latitude	Longitude	Precipitation (mm)	ET + RO (mm)	Infiltration Rate (mm)
35	Squamish	49.78	-123.16	2437	1258	1179
36	Tatlayoko Lake	51.67	-124.4	436	505	80*
37	Telegraph Creek	57.9141	-131.1712	345	342	80*
38	Terrace	54.47	-128.58	1341	575	766
39	Vancouver	49.18	-123.1811	1189	639	550
40	Vernon	50.23	-119.2921	500	577	80*
41	Victoria	48.65	-123.4291	883	671	212
42	Warfield	49.11	-117.74	779	656	123
43	White Rock	49.02	-122.8036	1108	640	468
44	Williams Lake	52.18	-122.1387	451	497	80*

* Annual infiltration rate assigned a minimum rate of 80 mm/year

From: Core 6 Environmental. (2017). Estimation of Regional Infiltration Rates in British Columbia, Protocol 2 Groundwater Model.

Figure – Infiltration Map



From: Core 6 Environmental. (2017). Estimation of Regional Infiltration Rates in British Columbia, Protocol 2 Groundwater Model.