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NOTE TO READER

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CSAP has recommended that Approved Professionals use their professional judgement[1] in applying any guidance, including this document. As the science upon which contaminated sites remediation is based is relatively young and because no two sites that involve the natural environment are the same, the need to exercise professional judgement within the regulatory process is recognized.

Ultimately, submissions for *Environmental Management Act* instruments need to meet regulatory requirements. The onus is on qualified professionals and Approved Professionals to document the evidence upon which their recommendations depend.

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The conclusions and recommendations of this document are based upon applicable legislation and policy existing at the time the document was prepared. Changes to legislation and policy may alter conclusions and recommendations.

[1] https://csapsociety.bc.ca/wp-content/uploads/ATT-3_-CSAP-Professional-Judgement-May2nd.pdf

Technical Memorandum

To:	Technical Review Committee	**From:**	Erin Robson and Ilya Biniowsky
Company:	Contaminated Sites Approved Professionals Society		**SLR Consulting (Canada) Ltd.**
cc:		**Date:**	November 2, 2023
		Project No.:	204.099027.00001

RE: Using the Groundwater Protection Model and Protocol 2 Site-Specific Standards

SLR Consulting (Canada) Ltd. has developed the attached spreadsheet tools for the Contaminated Sites Approved Professionals (CSAP) Society:

- CSAP P2 SSS GPM Relief Book WLn_WLr.xlsx
- CSAP P2 SSS GPM Relief Book AL_PL.xlsx
- CSAP P2 SSS GPM Relief Book RLld_RLhd.xlsx
- CSAP P2 SSS GPM Relief Book CL_IL.xlsx

The tools are intended to assist members and practitioners in determining whether the BC Groundwater Protection Model (GPM) and Protocol 2 (P2) Site-Specific Soil Standards (SSS) may be beneficial at sites as an alternative to adopting published numerical standards in Schedule 3.1 Part 1 of the BC Contaminated Sites Regulation (CSR) and Protocol 4 regional background values.

The tools above are intended for general educational/informational purposes only. Values represented in the tools may vary slightly from BC CSR Schedule 3.1 values or values obtained by using the BC GPM due to numerical rounding and other computational variances. **The tools should not be relied upon directly for developing site-specific soil standards.**

This supporting technical memorandum provides an overview of considerations for developing P2 SSS using the GPM, guidance for modification of key input parameters, and instructions and examples for use of the CSAP P2 SSS GPM Relief Book tools.

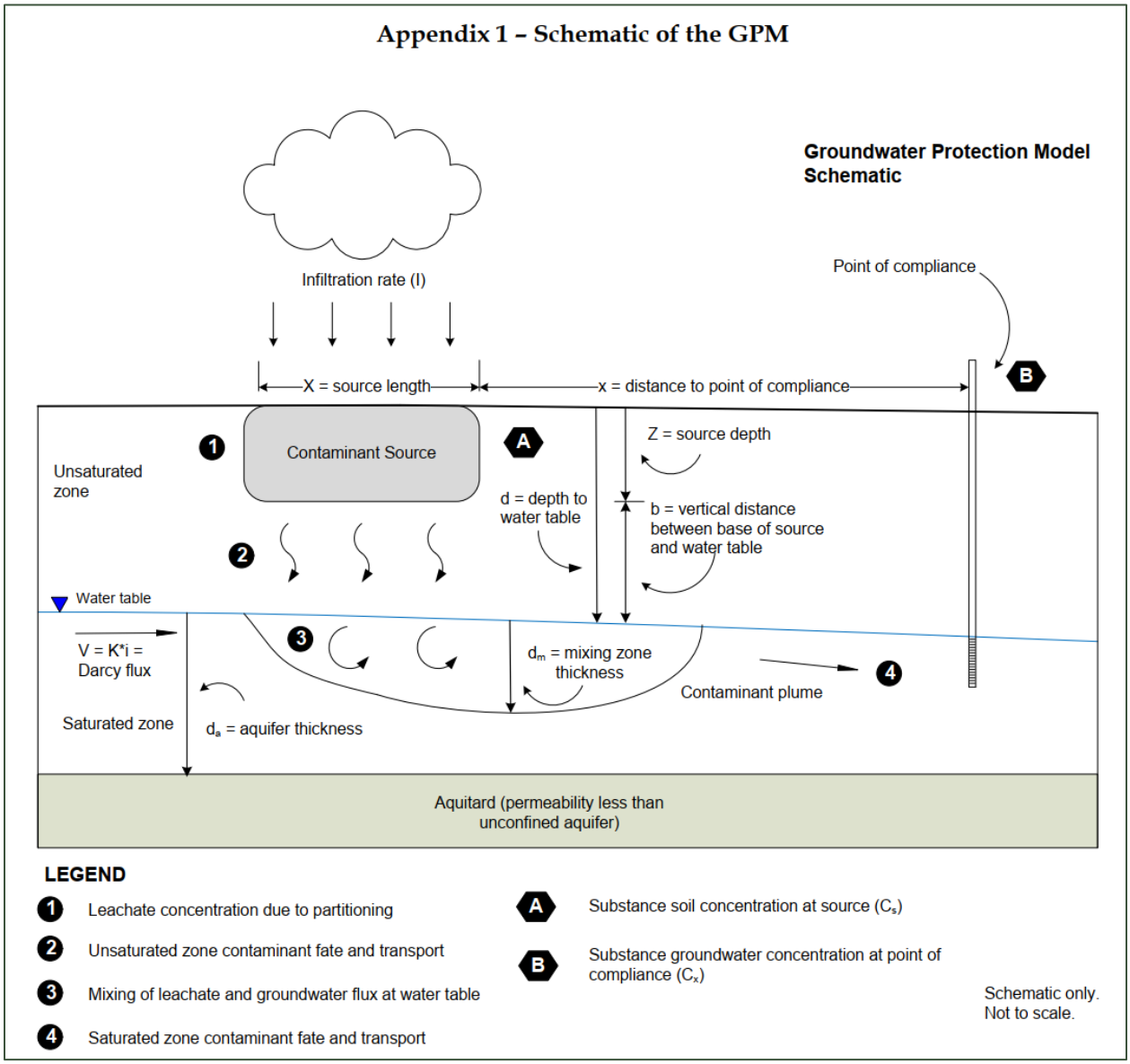
Supporting Documents

There are four key documents relevant to the development of P2 SSS, including:

- Protocol 2 – Site-Specific Numerical Soil Standards, and associated Core6 companion document [1]
- Technical Guidance 13 – Groundwater Protection Model (TG13).
- Technical Guidance 24 – Site-Specific Numerical Soil Standards Model Parameters (TG24).
- CSR Schedule 3.1 Part 1 Matrix Numerical Soil Standards (for comparison of other applicable site-specific factors and determination of lowest applicable standard).

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

Protocol 27 – Soil leachate Tests for Use in Deriving Site-Specific Numerical Soil Standards is also relevant if using leachate tests to develop P2 SSS but was outside the scope of the current study. For convenient reference, an overview of the GPM is shown below (reproduced from Appendix 1 of TG24).



GPM Input Parameters

There are 18 input parameters within the GPM that can be modified to develop P2 SSS. For the purposes of this study, we focused on **six key input parameters**: infiltration (I); fraction of organic carbon (foc); distance to point of compliance (x); vertical distance between base of source and water table (b); average linear velocity (v) and soil pH. Two of these key inputs (b and v), are model-calculated values but are derived from user-modifiable inputs.

General guidance for modification of these six input parameters is provided below; however, other than for modifying site-specific infiltration rate, prior to using the GPM to adjust input parameters (variables) from their defaults, it is highly recommended to have developed a good conceptual site model (CSM).

Infiltration

As indicated in TG24 Appendix 4, the first recommended step in using the GPM should be to use "site-specific" infiltration data. Despite the reference to "site-specific" data, P2 indicates that the infiltration rates must be taken directly from the list of regional values presented in P2 Appendix 1 Table 1 or interpolated between mapped locations using the procedure outlined in TG24. There are 44 urban centres listed in P2 Appendix 1 Table 1.

For the purposes of this study, 13 infiltration rates were used to represent the range of infiltration values presented in P2. In addition, the urban centres were sorted according to the Regions identified in Protocol 4 to allow for evaluation of whether a P2 SSS would provide relief beyond regional background values for a given substance.

Table 1: Modelled Infiltration Rates

P2 Appendix 1 Table 1 Urban Centre	Infiltration Rate (mm/yr)	Modelled Infiltration Group (mm/yr)
Ashcroft, Kamloops, Kelowna, Lillooet, Lytton, Osoyoos, Penticton, Salmon Arm, Vernon	80	80 – Region 3/8 (Thompson/Nicola/Okanagan)
Cranbrook, Golden, Skookumchuck	80	80 – Region 4 (Kootenay)
Quesnel, Tatlayoko Lake, Williams Lake	80	80 – Region 5 (Cariboo)
Burns Lake, Ootsa Lake Skins Lake Spillway, Telegraph Creek	80	80 – Region 6 (Skeena)
Dawson Creek, Fort Nelson / Prince George	80 / 81	81 – Region 7 (Omineca/Peace)
Smithers / Dease lake	94 / 111	111 – Region 6 (Skeena)
Fort St John	117	117 – Region 7 (Omineca/Peace)
Creston / Warfield	118 / 123	123 – Region 4 (Kootenay)
Victoria	212	212 – Region 1 (Vancouver Island)
Pemberton	275	275 – Region 2 (Lower Mainland)
Nakusp / Nelson / Revelstoke	277 / 312 / 311	312 – Region 4 (Kootenay)
Saturna Island	314	314 – Region 1 (Vancouver Island)
North Cowichan	445	445 – Region 1 (Vancouver Island)
White Rock	468	468 – Region 2 (Lower Mainland)
Comox	538	538 – Region 1 (Vancouver Island)
Vancouver	550	550 – Metro Vancouver
Abbotsford, Hope, Pitt Meadows, Port Alberni, Port Hardy, Prince Rupert, Squamish, Terrace	766 - 1731	Excluded – infiltration rate > default

Locations with infiltration rates exceeding the default GPM infiltration value (550 mm/yr, representing Vancouver) were excluded from the study as modifications above 550 mm/yr do not provide relief from the CSR Schedule 3.1 Part 1 numerical soil standards.

Fraction of Organic Carbon

For organic substances, the GPM is sensitive to the value entered for fraction of organic carbon (foc). As such, the GPM can only be modified using site-specific data.

A lower foc value will result in a lower (more stringent) standard. In many instances, site stratigraphy is complex and has layered soil horizons that could inherently have different foc values. Furthermore, foc is a factor in calculations in the GPM for the partitioning, unsaturated transport and saturated transport modules. However, only one site-specific foc value may be selected to represent the foc condition in the GPM for a site.

As such, the input value of a site-specific foc value requires careful professional judgement and should be selected using a conservative approach. Where sufficient representative site-specific soils foc data is not available or if the CSM is not well-defined, a conservative approach should be taken such as using the default foc.

Distance to Point of Compliance

As outlined in P2 Section 5.1.3, the distance to point of compliance (x) can only be modified from its default parameter value of 10 m when site-specific parameters are available for source dimensions (length [X], width [Y] and depth [Z]). P2 Section 5.1.1 outlines the specific criteria for determining source dimensions for petroleum hydrocarbons, other organics, and inorganic substances.

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 edge of 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 Regulation.
- 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 edge of 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 Regulation at the downgradient property boundary.

Vertical Distance between Base of Source and Water Table

Modelled standards for organic substances are sensitive to changes in depth to water (d). As indicated in P2, depth to water can only be modified using site-specific data and must be modified in conjunction with site-specific source dimensions as outlined in P2 Section 5.1.1.

The model is only sensitive to the difference between the depth to the base of the source (Z, default value 3 m) and the depth to water (d, default value 3 m), not the values themselves. This is calculated in the GPM as the “vertical distance between base of source and water table” (d-Z). For the purposes of this study, the more relevant calculated value “b” was selected rather than varying individually the source depth and/or depth to water user inputs.

Average Linear Groundwater Velocity

For both organic and inorganic substances, the GPM is sensitive to the average linear groundwater velocity in the saturated zone, which is calculated using the inputs for hydraulic conductivity, hydraulic gradient and the effective porosity. The GPM can only be modified using site-specific data for hydraulic conductivity and gradient, whereas the effective porosity can be determined using either literature or site-specific values. For the purposes of this study, the more relevant calculated value "v" was selected rather than varying the direct user inputs of hydraulic conductivity, hydraulic gradient and/or effective porosity.

Similar to other inputs, a single site-specific value of each of hydraulic conductivity, hydraulic gradient and effective porosity must be selected to represent the site. Below the default value (30.27 m/yr), a low average linear groundwater velocity value will result in a higher (less stringent) standard for organics due to increased effects of bio-attenuation. Above the default value, a higher average linear groundwater velocity value will result in a higher standard for both organic and inorganic substances due to the enhanced effects of dilution and dispersion.

As outlined in TG24, since saturated transport in the GPM is simulated in the shallowest unconfined groundwater flow system, the hydraulic conductivity, gradient, and thickness should be measured through in-situ field investigations and represent conditions in the unconfined flow system. Technical guidance on site investigations can be found in Technical Guidance 8 "Groundwater Investigation and Characterization". For sites where there are perched water tables or where the hydraulic conductivity, gradient and aquifer thickness cannot be determined, the default model parameter values will need to be used.

Soil pH

Soil pH is listed in TG24 as the most sensitive model input parameter for inorganic substances; however, as the most sensitive of these substances already have pH-dependent CSR Schedule 3.1 standards, the relief achieved through modification of pH alone is not as pronounced as some other GPM input modifications. The presence of pH-dependent CSR matrix standards does give rise to a few other key considerations for use of P2 SSS, as discussed below.

Choosing a Site-Specific pH

The CSR Schedule 3.1 Part 1 matrix numerical soil standards list several standards dependent on soil pH value ranges. Conversely, when developing a P2 SSS, as with other parameters, only one site-specific pH value may be selected to represent the site. Soil pH is a factor in the partitioning module and unsaturated and saturated transport modules for inorganics and pentachlorophenol (PCP). As such, selection of an appropriate site-specific pH requires a well developed CSM and careful professional judgment at sites with layered stratigraphy, which could inherently have different pH ranges. The calculation of a site-specific pH should be conducted using a conservative approach. For the majority of substances, a lower pH value will result in a lower (more stringent) standard; for some substances, such as PCP and selenium, the opposite trend occurs.

CSR Schedule 3.1 pH-Ranges vs P2 SSS

The CSR pH-dependent standards are grouped into ranges, typically in 0.5-unit increments, and often, but not always, the standards were developed using the mid-point of each pH range. As a result, the GPM may calculate a more or less stringent standard than the CSR Schedule 3.1 standard even when using default values for all other inputs.

If the site-specific pH is lower than the mid-point of the given CSR Schedule 3.1 pH-dependent range, the GPM may not provide relief, **even when other inputs such as infiltration are adjusted**. In the case of PCP, a site-specific pH lower than the mid-point of the given CSR Schedule 3.1 pH-dependent range will give rise to a higher (less stringent) standard than that presented in the CSR.

Due to these differences in the way the CSR Schedule 3.1 standards were calculated compared to the GPM requirements, it is worthwhile to run a quick check with the GPM to see whether developing a P2 SSS using a site-specific pH would provide an advantage over using the CSR Schedule 3.1 Part 1 pH-dependent standards.

Acceptable Parameter Ranges

Acceptable ranges for site-specific model parameters are outlined in P2 Table 2. Care was taken within this study to only modify the input parameters within the allowable ranges.

Precluding Conditions

SSSs cannot be derived for petroleum hydrocarbon substances or potential co-contaminants on sites where mobile nonaqueous phase liquids (NAPLs) are present.

Additional P2 Requirements and TG24 Guidance

For those substances with pH-dependent CSR Schedule 3.1 standards (beryllium, cadmium, copper, lead, nickel, pentachlorophenol [PCP], and zinc), site-specific soil pH must be used to develop P2 SSS. For PCP, site-specific groundwater pH may also be required (AW-pathway only).

As indicated in TG24, when deriving SSSs protective of aquatic life for substances that depend on water hardness, site-specific data for water hardness (H) of the receiving environment is required.

Using the P2 SSS GPM Relief Books

The P2 SSS GPM relief books each have an Instruction Sheet that displays in detail how to use and interpret the workbook. The workbook is navigated by Excel hyperlinks and drop down filters and contains no macros to avoid the security concerns around imbedded macros. The P2 SSS GPM relief books each include 3 modes of display.

1 Summary Lookup table and supporting tables.

2 PCOC Overview Index and supporting tables.

3 Matrix index and supporting tables.

Summary Lookup Table

The Summary Lookup Table allows the user to use Excel drop down filters to choose the land use, potential contaminant of concern (PCOC), and water use of interest to see the lower and upper bounds of the six key individual GPM parameter values that may give relief (while keeping all but the one key GPM parameter at default values).

Example Summary Look Up Table - Commercial Land Use (CL) and Benzene

Table of Groundwater Protection Model (GPM) Parameter Ranges where GPM Results are Greater than BC CSR Schedule 3.1 Part 1

GPM Parameter Relief Ranges

Link to Instructions			Parameter →	Infiltration Rate (m/yr)		Fraction of Organic Carbon (-)		Distance to Point of Compliance (m)		Depth from Source to Water Table (m)		Average Linear Groundwater Velocity (m/yr)		pH of Soil (-)	
			Abbreviation →	I		foc		x		b		v		pHsoil	
Land Use ↓	PCOC ↓	Groundwater Use ↓	Link to Sheet ↓	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
CL	Benzene	DW	CL_Bz_DW	0.08	0.4	0.01	0.05	20	500	0.5	3.5	5	250	no relief	no relief
CL	Benzene	AWF	CL_Bz_AWF	0.08	0.5	0.01	0.05	20	500	0.5	3.5	5	250	no relief	no relief
CL	Benzene	AWM	CL_Bz_AWM	0.08	0.5	0.01	0.05	20	500	0.5	3.5	5	250	no relief	no relief

For example, the table above shows that adjusting infiltration rate to a value between 0.08 m/yr (lower allowable limit) and 0.4 m/yr will provide relief for benzene for the drinking water pathway at sites with commercial land use.

A column of links to the supporting worksheets allows the user to examine how the relief range was developed by comparing the GPM output to the CSR Schedule 3.1 values indicated in the Back Up Worksheets (example below). Results are colour-coded to highlight the default values used to determine the CSR standards, and to flag both where relief is evident, and where that relief is limited by a mandatory pathway such as human health intake or eco toxicity.

Example Back Up Worksheet - CL, Benzene, Drinking Water Use

Link to Index

Land Use: → CL
PCOC: → Benzene
Applicable GW Use: → DW
Minimum Mandatory Pathway Standard: → 250 µg/g

		Protocol 2 Constraint Note:								relief lower bound	relief upper bound
I	infiltration rate (m/yr)	a	**0.08**	**0.1**	**0.2**	**0.3**	**0.4**	0.45	0.5	0.55	0.08	0.4
	CSR Standard (µg/g)		0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035		
	BC GPM (µg/g)		**0.10**	**0.095**	**0.060**	**0.045**	**0.040**	0.035	0.035	0.035		
f_{oc}	fraction of organic carbon (-)	b	0.001	0.005	**0.01**	**0.015**	**0.02**	**0.03**	**0.04**	0.05	0.01	0.05
	CSR Standard (µg/g)		0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035		
	BC GPM (µg/g)		0.006	0.035	**0.10**	**0.30**	**0.65**	**2.5**	**7.0**	**20**		
x	distance to point of compliance (m)	b, c,d	10	**20**	**40**	**60**	**80**	**100**	**200**	**500**	20	500
	CSR Standard (µg/g)		0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035		
	BC GPM (µg/g)		0.035	**0.070**	**0.25**	**0.85**	**2.5**	**7.5**	**550**	**750**		
b	depth from source to water table (m)	b,c	0	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	0.5	3.5
	CSR Standard (µg/g)		0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035		
	BC GPM (µg/g)		0.035	**0.15**	**0.45**	**1.0**	**3.0**	**6.5**	**15**	**25**		
v	average linear groundwater velocity (m/yr)	b	5	**10**	30.27	50	100	**150**	**200**	250	5	250
	CSR Standard (µg/g)		0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035		
	BC GPM (µg/g)		**0.45**	**0.10**	0.035	0.030	0.035	**0.045**	**0.055**	**0.060**		
pH_{soil}	pH of soil (-)	b	5	5.5	6	6.500	7	7.5	8	9		
	CSR Standard (µg/g)		0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035		
	BC GPM (µg/g)		0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035		

Notes

GPM - BC Groundwater Protection Model
Change in Model Parameter keeps all other model parameters at default value
default value and BC CSR standard
bold - value of model parameter where the GPM result exceeds the BC CSR Standard
GPM result that exceeds the BC CSR Standard but exceeds the minimum mandatory standard
GPM result that exceeds the BC CSR Standard but does not exceed the minimum mandatory standard
red = maximum allowable value
blue = minumum allowable value

PCOC Overview Tables

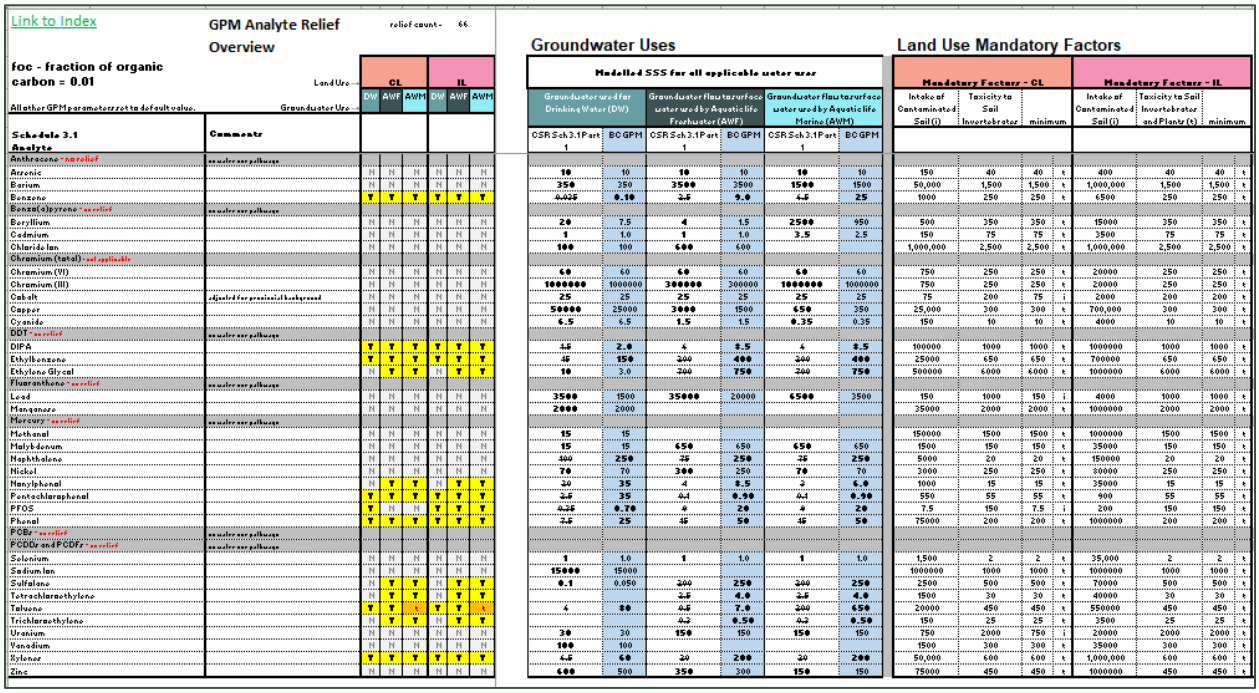
The PCOC Overview Tables are accessed through an index page showing the GPM input parameter value examined, a column with links to the worksheets and a column showing the total instances (count) of relief within each worksheet.

Overview Sheets Showing Where a Specific Groundwater Protection Model (GPM) Parameter Value Gives Relief over CSR Schedule 3.1 PCOCs

Parameter Setting	Link to Sheet	Count of Relief Instances*
I - infiltration rate = 0.08 m/yr	I-0.08	433
I - infiltration rate = 0.1 m/yr	I-0.1	397
I - infiltration rate = 0.2 m/yr	I-0.2	369
I - infiltration rate = 0.3 m/yr	I-0.3	337
I - infiltration rate = 0.4 m/yr	I-0.4	248
I - infiltration rate = 0.45 m/yr	I-0.45	183
I - infiltration rate = 0.5 m/yr	I-0.5	71
I - infiltration rate = 0.55 m/yr	I-0.55	9
foc - fraction of organic carbon = 0.001	foc-0.001	0
foc - fraction of organic carbon = 0.005	foc-0.005	9
foc - fraction of organic carbon = 0.01	foc-0.01	253
foc - fraction of organic carbon = 0.015	foc-0.015	261

The PCOC Overview Worksheets show in a yes/no fashion where relief might be found across all the relevant substances under different land and water uses for a particular GPM input value. PCOC Overview Worksheets are included for a broad input range of the GPM parameters assessed in this work (i.e., infiltration, foc, distance to point of compliance, depth between source and water table, average linear velocity and soil pH).

Example Overview Worksheet – CL_IL, Fraction of Organic Carbon = 0.01



Link to Index

GPM Analyte Relief Overview

relief count - 66

foc - fraction of organic carbon = 0.01

Land Use → CL IL

All other GPM parameters set to default value. Groundwater Use →

Schedule 3.1 Analyte	Comments	CL DW	CL AWF	CL AWM	IL DW	IL AWF	IL AWM
Anthracene - no relief	no water use pathways						
Arsenic		N	N	N	N	N	N
Barium		N	N	N	N	N	N
Benzene		Y	Y	Y	Y	Y	Y
Benzo(a)pyrene - no relief	no water use pathways						
Beryllium		N	N	N	N	N	N
Cadmium		N	N	N	N	N	N
Chloride Ion		N	N	N	N	N	N
Chromium (total) - not applicable							
Chromium (VI)		N	N	N	N	N	N
Chromium (III)		N	N	N	N	N	N
Cobalt	adjusted for provincial background	N	N	N	N	N	N
Copper		N	N	N	N	N	N
Cyanide		N	N	N	N	N	N
DDT - no relief	no water use pathways						
DIPA		Y	Y	Y	Y	Y	Y
Ethylbenzene		Y	Y	Y	Y	Y	Y
Ethylene Glycol		N	Y	Y	N	Y	Y
Fluoranthene - no relief	no water use pathways						
Lead		N	N	N	N	N	N
Manganese		N	N	N	N	N	N
Mercury - no relief	no water use pathways						
Methanol		N	N	N	N	N	N
Molybdenum		N	N	N	N	N	N
Naphthalene		N	Y	Y	N	Y	Y
Nickel		N	N	N	N	N	N
Nonylphenol		N	Y	Y	N	Y	Y
Pentachlorophenol		Y	Y	Y	Y	Y	Y
PFOS		Y	Y	Y	Y	Y	Y
Phenol		Y	Y	Y	Y	Y	Y
PCBs - no relief	no water use pathways						
PCDDs and PCDFs - no relief	no water use pathways						
Selenium		N	N	N	N	N	N
Sodium Ion		N	N	N	N	N	N
Sulfolane		N	Y	Y	N	Y	Y
Tetrachloroethylene		N	Y	Y	N	Y	Y
Toluene		Y	Y	Y	Y	Y	Y
Trichloroethylene		N	Y	Y	N	Y	Y
Uranium		N	N	N	N	N	N
Vanadium		N	N	N	N	N	N
Xylenes		Y	Y	Y	Y	Y	Y
Zinc		N	N	N	N	N	N

Groundwater Uses — Modelled SSS for all applicable water uses

Groundwater used for Drinking Water (DW)		Groundwater flux to surface water used by Aquatic life Freshwater (AWF)		Groundwater flux to surface water used by Aquatic life Marine (AWM)	
CSR Sch 3.1 Part 1	BC GPM	CSR Sch 3.1 Part 1	BC GPM	CSR Sch 3.1 Part 1	BC GPM
10	10	10	10	10	10
350	350	3500	2500	1500	1500
~~0.035~~	0.10	~~3.5~~	9.0	~~4.5~~	25
20	7.5	4	1.5	2500	950
1	1.0	1	1.0	3.5	2.5
100	100	600	600		
60	60	60	60	60	60
1000000	1000000	300000	300000	1000000	1000000
25	25	25	25	25	25
50000	25000	3000	1500	650	350
6.5	6.5	1.5	1.5	0.35	0.35
~~1.5~~	2.0	4	~~8.5~~	4	~~8.5~~
~~45~~	150	~~200~~	400	~~200~~	400
10	~~2.0~~	~~200~~	750	~~200~~	750
3500	1500	35000	20000	6500	3500
2000	2000				
15	15				
15	15	650	650	650	650
~~100~~	250	~~75~~	250	~~75~~	250
70	70	300	250	70	70
~~20~~	35	4	~~8.5~~	2	~~6.0~~
~~3.5~~	35	0.1	0.90	0.1	0.90
~~0.35~~	0.70	4	20	4	20
~~2.5~~	25	~~45~~	50	~~45~~	50
1	1.0	1	1.0	1	1.0
15000	15000				
0.1	0.050	~~200~~	250	~~200~~	250
		~~2.5~~	4.0	~~2.5~~	4.0
4	40	~~0.5~~	7.0	~~200~~	650
		~~0.2~~	0.50	~~0.2~~	0.50
20	20	150	150	150	150
100	100				
~~4.5~~	60	~~30~~	200	~~30~~	200
600	500	350	300	150	150

Land Use Mandatory Factors

Mandatory Factors - CL: Intake of Contaminated Soil (I)	Mandatory Factors - CL: Toxicity to Soil Invertebrates	minimum		Mandatory Factors - IL: Intake of Contaminated Soil (I)	Mandatory Factors - IL: Toxicity to Soil Invertebrates and Plants (t)	minimum	
150	40	40	t	400	40	40	t
50,000	1,500	1,500	t	1,000,000	1,500	1,500	t
1000	250	250	t	6500	250	250	t
500	350	350	t	15000	350	350	t
150	75	75	t	3500	75	75	t
1,000,000	2,500	2,500	t	1,000,000	2,500	2,500	t
750	250	250	t	20000	250	250	t
750	250	250	t	20000	250	250	t
75	200	75	i	2000	200	200	t
25,000	300	300	t	700,000	300	300	t
150	10	10	t	4000	10	10	t
100000	1000	1000	t	1000000	1000	1000	t
25000	650	650	t	700000	650	650	t
500000	6000	6000	t	1000000	6000	6000	t
150	1000	150	i	4000	1000	1000	t
35000	2000	2000	t	1000000	2000	2000	t
150000	1500	1500	t	1000000	1500	1500	t
1500	150	150	t	35000	150	150	t
5000	20	20	t	150000	20	20	t
3000	250	250	t	80000	250	250	t
1000	15	15	t	35000	15	15	t
550	55	55	t	900	55	55	t
7.5	150	7.5	i	200	150	150	t
75000	200	200	t	1000000	200	200	t
1,500	2	2	t	35,000	2	2	t
1000000	1000	1000	t	1000000	1000	1000	t
2500	500	500	t	70000	500	500	t
1500	30	30	t	40000	30	30	t
20000	450	450	t	550000	450	450	t
150	25	25	t	3500	25	25	t
750	2000	750	i	20000	2000	1500	t
1500	300	300	t	35000	300	300	t
50,000	600	600	t	1,000,000	600	600	t
75000	450	450	t	1000000	450	450	t

The colour yellow indicates where relief is not constrained by the minimum mandatory standard while orange highlighting indicates where relief is constrained by the minimum mandatory standard (and an abbreviation indicating which mandatory human health or ecological toxicity pathway was most constraining).

To the right of the main table on each Overview Worksheet are supporting tables showing the values for the CSR Schedule 3.1 Part 1 matrix standards (groundwater pathway and mandatory standards) along with the GPM results so a user can verify how the relief was determined.

2-Parameter Matrices

The 2-Parameter Matrix sheets show the potential additional relief dynamics by changing more than one GPM variable at a time for a particular PCOC. Five GPM parameters (fraction of organic carbon, distance to point of compliance, depth between source and water table, average groundwater velocity and soil pH) are coupled with infiltration rates and municipalities listed in BC Protocol 2 Appendix 1. The 2-Parameter Matrices are accessed through drop down filters in an index sheet, which has links to the supporting sheets and summarizes the relative counts of relief within each supporting sheet.

Example 2-Parameter Matrix Index – Infiltration and Fraction of Organic Carbon

2-Parameter Matrices Showing Ranges of Groundwater Protection Model Relief

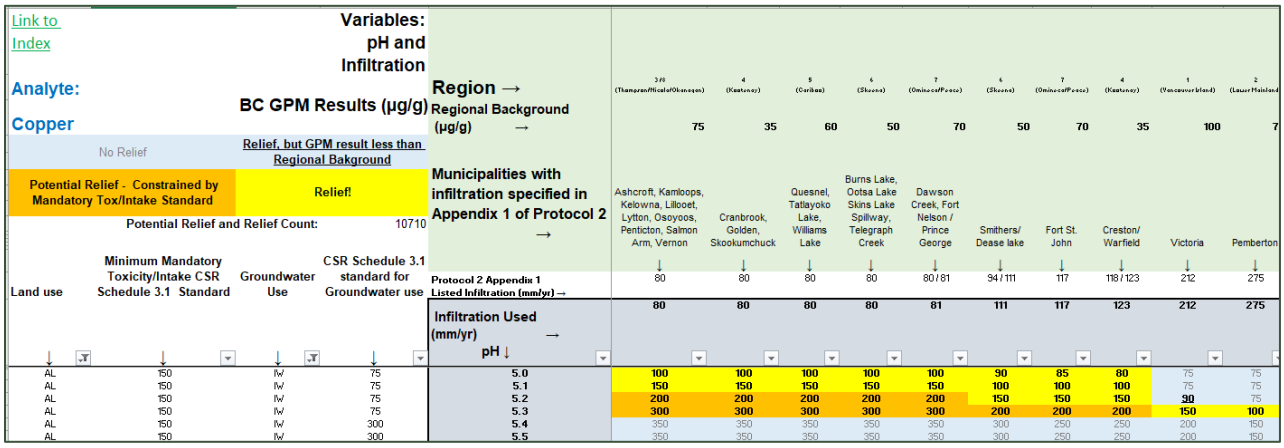
Link to Instructions

PCOC	GPM Parameter 1	GPM Parameter 2	Link to Sheet	Count of Relief Instances*
Benzene	Infiltration	fraction of organic carbon	foc-Infilt_Bz	4984
Diisopropanolamine (DIPA)	Infiltration	fraction of organic carbon	foc-Infilt_DIPA	8498
Ethylbenzene	Infiltration	fraction of organic carbon	foc-Infilt_EBz	2996
Ethylene Glycol	Infiltration	fraction of organic carbon	foc-Infilt_EGly	3745
Methanol	Infiltration	fraction of organic carbon	foc-Infilt_Me	1582
Naphthalene	Infiltration	fraction of organic carbon	foc-Infilt_Naph	0
Nonylphenols	Infiltration	fraction of organic carbon	foc-Infilt_NNE	3318
Pentachlorophenol	Infiltration	fraction of organic carbon	foc-Infilt_PCP	6692
Perfluorooctane Sulfonate	Infiltration	fraction of organic carbon	foc-Infilt_PFOS	2114
Phenol	Infiltration	fraction of organic carbon	foc-Infilt_Phen	4970
Sulfolane	Infiltration	fraction of organic carbon	foc-Infilt_Sulf	7735

The GPM results found by combining the two parameter modifications are displayed in a matrix. Results are colour coded to indicate relief unconstrained or constrained by minimum mandatory standards similar to the PCOC Overview Worksheet tables. Drop-down filters allow the user to narrow the focus to a particular land use or water use.

Further consideration is also given to the BC Protocol 4 Table 1 regional background soil concentrations (for inorganic PCOCs) listed for the regions in which each of the listed municipalities lie. Relief colour highlighting is removed if the regional background value is greater than or equal to the GPM result.

Example pH and Infiltration Matrix, AL, Copper, Irrigation groundwater use:



Link to Index	Variables: pH and Infiltration	Region →	3/4 (Thompson/Nicola/Okanagan)	4 (Kootenay)	5 (Cariboo)	6 (Skeena)	7 (Omineca/Peace)	6 (Skeena)	7 (Omineca/Peace)	4 (Kootenay)	1 (Vancouver Island)	2 (Lower Mainland
Analyte:	BC GPM Results (µg/g)	Regional Background (µg/g) →	75	35	60	50	70	50	70	35	100	7
Copper	No Relief / Relief, but GPM result less than Regional Bakground / Potential Relief - Constrained by Mandatory Tox/Intake Standard / Relief!	Municipalities with infiltration specified in Appendix 1 of Protocol 2 →	Ashcroft, Kamloops, Kelowna, Lillooet, Lytton, Osoyoos, Penticton, Salmon Arm, Vernon	Cranbrook, Golden, Skookumchuck	Quesnel, Tatlayoko Lake, Williams Lake	Burns Lake, Ootsa Lake Skins Lake Spillway, Telegraph Creek	Dawson Creek, Fort Nelson / Prince George	Smithers/ Dease lake	Fort St. John	Creston/ Warfield	Victoria	Pemberton
Potential Relief and Relief Count: 10710		Protocol 2 Appendix 1 Listed Infiltration (mm/yr) →	80	80	80	80	80 / 81	94 / 111	117	118 / 123	212	275
Land use	Minimum Mandatory Toxicity/Intake CSR Schedule 3.1 Standard / Groundwater Use / CSR Schedule 3.1 standard for Groundwater use	Infiltration Used (mm/yr) →	80	80	80	80	81	111	117	123	212	275
		pH ↓										
AL	150 / lw / 75	5.0	100	100	100	100	100	90	85	80	75	75
AL	150 / lw / 75	5.1	150	150	150	150	150	100	100	100	75	75
AL	150 / lw / 75	5.2	200	200	200	200	200	150	150	150	90	75
AL	150 / lw / 75	5.3	300	300	300	300	300	200	200	200	150	100
AL	150 / lw / 300	5.4	350	350	350	350	350	300	250	250	200	150
AL	150 / lw / 300	5.5	350	350	350	350	350	300	250	250	200	150

In the example above, pH modifications between 5.0 and 5.3 coupled with infiltration rate modifications between 80 and 123 mm/yr result in consistent relief; whereas, at infiltration rates greater than 123 mm/yr, relief is only found at pH of 5.3 and in some cases (bold, underlined, no highlight) the use of Protocol 4 Table 1 regional background values will provide greater relief.

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Closure

We trust that CSAP members and fellow practitioners will find these tools useful for assessing whether to pursue the use of P2 SSS at their sites and we welcome any feedback for future improvements or further study.

Regards,

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Attachments
CSAP P2 SSS GPM Relief Book-WLn_WLr.xlsx
CSAP P2 SSS GPM Relief Book-AL_PL.xlsx
CSAP P2 SSS GPM Relief Book-RLld_RLhd.xlsx
CSAP P2 SSS GPM Relief Book-CL_IL.xlsx