Draft Discussion Document: For Stakeholder Consultation
Comment Period Closes: Aug. 28, 2015

CSR OMNIBUS UPDATING: Proposed Amendments to Schedule 5 Soil to Water Pathway Standards

Author: George Szefer **Date:** June 19, 2015

Summary of Proposed Updates for 2015/2016 Stage 10 amendment to CSR

The ministry proposes to modify the Contaminated Sites Soil Task Group (CSST) 1996 [1, 2] Groundwater Protection Model used to derive the Contaminated Sites Regulation [3] Schedule 5 soil to groundwater protective standards to:

a. incorporate advances related to the science of modelling contaminant transport in soil and water; and,
b. ensure consistency in the use of the model, or model elements, between the various CSR Protocols and Technical Guidance.

Details of the changes to the model for these two purposes are presented in section 4 below.

1. Introduction

Schedule 5 of the BC Contaminated Sites Regulation (CSR) contains matrix numerical soil standards for both human health and environmental protection. The existing matrix standards are based on five land uses and nine site-specific factors. Application of individual site-specific factors varies by land use. A summary of the current Schedule 5 framework of land uses and associated site-specific factors is shown in Table 1.

Table 1. CSR Schedule 5 site-specific factors by land use*.

COLUMN I	COLUMN II	COLUMN III	COLUMN IV	COLUMN V	COLUMN VI
Site-specific Factor	SOIL STANDARD FOR PROTECTION OF SITE-SPECIFIC FACTOR				
	Agricultural (AL)	Urban Park (PL)	Residential (RL)	Commercial (CL)	Industrial (IL)
HUMAN HEALTH PROTECTION					
Intake of contaminated soil	X	X	X	X	X
Groundwater used for drinking water	X	X	X	X	X
ENVIRONMENTAL PROTECTION					
Toxicity to soil invertebrates and plants	X	X	X	X	X
Livestock ingesting soil and fodder	X				
Major microbial functional impairment	X				
Groundwater flow to surface water used by aquatic life	X	X	X	X	X
Groundwater used for livestock watering	X				
Groundwater used for irrigation	X	X	X		

This document outlines proposed updates and revisions to the CSST, 1996 [1] Protocol for the derivation of the soil to water pathway site-specific factor standards for human health and environmental protection in Schedule 5. Following from Table 1, these consist of:

- groundwater used for drinking water;
- groundwater flow to surface water used by aquatic life (freshwater or marine);
- groundwater used for livestock watering; and,
- groundwater used for irrigation.

The proposed updates and revisions to the CSST, 1996 [1] Protocol are based on review of the current science, underlying policies, other protocols, and literature/legislative review of models used in other jurisdictions and agencies. The updates are also based on the recommendations related to updating the derivation Protocol provided by the Science Advisory Board for Contaminated Sites in British Columbia (SABCS) in the SABCS, 2005 Scientific Review document [4].

2. Current Protocol

The current protocol used to derive the CSR Schedule 5 matrix numerical human health and environmental protection soil standards for the soil to water pathway is the CSST, 1996 [1] protocol. The current protocol [1] provides for calculation of soil standards that are protective of water or groundwater. The derivation methods for the various soil to water pathway protective standards are described in section B2.4 (Environmental Soil Quality Standards for the Protection of Groundwater) and C3.2 (Toxicity from Transfer of Contaminants to Groundwater Used as Drinking Water) of the protocol [1] with associated substance values provided in Appendix B of the protocol [1].

The current derivation method is formulated on a conceptual model of a contaminated site. The model framework (i.e., the Groundwater Protection Model (GPM), also known as the CSST [1] model), simulates the transport of a substance from soil to groundwater and the subsequent transport of the substance in groundwater to a receptor. Specifically, contaminant transport is modelled through four integrated physical/chemical components, consisting of:

- substance leachate generation in the unsaturated zone via substance partitioning between soil, soil pore air, and soil pore water;
- substance transport through the unsaturated zone;
- substance leachate mixing with groundwater; and,
- substance transport through the saturated zone to a receptor.

The GPM is used in a backward calculation mode to calculate soil matrix standards that are protective of water. This process involves specification of the applicable standards at the receptor with subsequent backward calculation of the allowable substance concentrations in soil at the source area. The applicable standards at the receptor are

based on the water uses as provided in CSR Schedule 6 (drinking water, aquatic life (freshwater and marine), livestock watering and irrigation water).

The GPM is based on assumptions generally typical of the climatic conditions of the lower Fraser River/Vancouver area of and groundwater characteristics typical of those found with the Fraser River sands of the Fraser River delta area of the Province. Other model assumptions include: source area characteristics, soil and substance characteristics and properties, depth to groundwater, distance to receptor, and contaminant transport and attenuation processes and limitations.

Attenuation in the GPM includes both physical and chemical mechanisms. Physical mechanisms include dilution (mixing) and dispersion. Chemical mechanisms include partitioning (adsorption/desorption) and biological degradation (organics only).
Soil matrix standards are calculated for both organic and inorganic substances using the GPM. For non-polar organic substances, partitioning is a function of the organic carbon coefficient of the substance and the amount of organic carbon in the soil. For weakly ionizing organics, partitioning is additionally influenced by soil pH. Partitioning of inorganics is based on distribution coefficients calculated as a function of soil pH.

The flow and transport processes in the GPM are based on a steady-state analytical solution in the unsaturated zone (Kool et al, 1994 [5]) and a transient analytical solution in the saturated zone (Domenico, 1987 [6]). The Domenico solution is similar to the analytical solution used in the BIOSCREEN model (US EPA, 1996 [7]).

The GPM also links with other ministry protocols consisting primarily of Protocol 2 Site-Specific Numerical Soil Standards [8] and Protocol 13 Screening Level Risk Assessment [9]. The GPM also links with Protocol 21 Water Use Determination [10] and ministry guidance Technical Guidance 15 Concentration Limits for the Protection of Aquatic Receiving Environments [11].

In Protocol 2 [8], the GPM is used to develop site-specific numerical soil standards based on site-specific substance properties and site characteristics (i.e., modification of the default values in the GPM). In Protocol 13 [9], a model similar to the GPM is used for prediction of substance transport in groundwater to a receptor. Protocol 21 [10] includes specification of distances from contaminated sites where water uses are deemed to apply. Technical Guidance 15 [11] provides specification of where the CSR Aquatic Life (AW) standards are deemed to apply in proximity to a receiving environment.

Based on the many linkages and interdependencies between the GPM and other ministry protocols and guidance, updating and revision of the GPM for the purposes of deriving CSR Schedule 5 soil to groundwater protective standards under the CSST, 1996 [1] protocol must also ensure appropriate harmonization of any such changes with Protocols 2 [8] and 13 [9] and ensure consistency with other CSR protocols and guidance. In addition, to the extent practicable, harmonization of the proposed new GPM with other agency groundwater models (e.g., CCME, 2006 [12] and CCME, 2008 [13]) is also desired.

3. Agency/Literature Review

A review of existing recommendations provided by the SABCS [4] and others known to the ministry, and a limited literature review of models used in other jurisdictions, was undertaken as part of proposed updating of the GPM to be used under the proposed new modified CSST, 1996 [1] protocol. The results of this review are summarized below.

3.1 SABCS Recommendations

A review of the CSST, 1996 [1] protocol was undertaken previously by the SABCS (SABCS, 2005 [4]). The SABCS also reviewed the GPM as a component of their recommendations for the development of Screening Level Risk Assessment (SABCS, 2005 [14]). Additional recommendations related to the GPM have also been provided to the ministry by the Society of Contaminated Sites Approved Professionals of British Columbia (CSAP), 2011 [15], other stakeholders and practitioners as part of development of other ministry protocols and guidance. The primary focus of these reviews and recommendation relate to: selection of soil, groundwater and site characteristics; contaminant source area values; contaminant substance properties; and, the transport assumptions and analytical solutions used in the GPM.

A detailed comparison of the existing GPM and overall SABCS/other recommendations is provided in Appendix A, Table A1. Ministry responses to the various recommendations and the ministry's proposed changes to the GPM are also noted in Table A1. Table A1 also provides an assessment of the extent of harmonization realised for the proposed changes to the GPM and related ministry protocols (i.e., Protocol 2 [8] and Protocol 13 [9]).

3.2 Literature Review

A limited literature review was conducted as part of updating of the GPM. This consisted of review of other Canadian agency models that are used for the protection of groundwater, i.e., models as used for the development of soil standards to protect groundwater or models that are used for the direct development of groundwater standards. The models reviewed on a limited basis were:

- CCME Soil Protocol (CCME, 2006 [12]);
- CCME Canada Wide Standards for PHCs (CCME, 2008 [13]);
- CCME Groundwater Protocol (CCME, 2015 [16]);
- Alberta Tier I Remediation Guidelines (Alberta , 2014 [17]); and,
- Ontario Standards for Contaminated Sites (Ontario MoE, 2011 [18]).

The results of the literature review have been incorporated into Appendix A, Table A1, either as a comparison model (CCME, 2006 [12]) or as part of response comments.

4. Proposed Updates - Stage 10 Amendments

The proposed updates to the CSST GPM [1], as based on the recommendations provided/known to the ministry and the limited literature review conducted to date are summarized as follows. The proposed updates, and related updates to Protocol 2 [8] and Protocol 13 [9] for harmonization, are provided in greater detail with supporting information in Appendix A, Table A1.

4.1 Changes to the Model to Incorporate New Science

The ministry proposes to update the CSST GPM [1] as follows.

1. Revise the model to:
    a. upgrade the graphical user interface;
    b. provide greater transparency in parameter selection/input and substance properties; and,
    c. update the model documentation and help file information.

2. Modify the existing soil type used in the model to:
    a. be more broadly representative of coarse-grained soil conditions in BC; and
    b. enhance consistency and harmonization with the coarse-grained soil type as provided in the CCME 2006 [12] soil protocol.

3. Adopt the US EPA SSG [19] partition coefficients for existing and proposed matrix numerical substances except use internally developed distribution coefficient (K_d) values for barium, chloride, mercury and sodium.

4. Develop and incorporate lead and copper K_d isotherms using the US EPA 3MRA [20] database and US EPA SSG [19] default input values.

5. Adopt the Domenico (1987) [6] two-dimensional steady-state saturated zone transport model for harmonization with Protocol 13 [9].

6. Adopt the new biodegradation rates as provided in Axiom Environmental Inc., 2011 [21]. Remove the biodegradation rates for tetrachloroethylene and trichloroethylene in the proposed new model to harmonize with Protocol 13 [9].

7. Revise the average linear groundwater velocity to be more consistent with the CCME, 2006 [12] coarse-grained soil type to enhance harmonization with CCME, 2006 [12] assumptions.

8. Use the United States Department of Energy (US DOE) Risk Assessment Information System (RAIS) database [22] to obtain soil organic carbon-water partitioning coefficient (K_{oc}) values.

9. Adopt the pH-dependent K_{oc} isotherm for pentachlorophenol as documented in SABCS, 2005 [14].

10. Incorporate variable soil pH ranges for ionizing organic substances where sufficient soil pH-K_{oc} relationship data and time/resources are available.

11. Evaluate adoption of a modified solubility constraint (50% of pure-phase solubility) for organic substances.

12. Revise the background adjustment to report either the background concentration or the calculated standard, whichever is greater.

13. Remove the leachate quality standards of the Hazardous Waste Regulation [23] as hazardous waste soil quality is assessed separately under the Contaminated Sites Regulation [3].

14. Modify the rounding rule to report matrix numerical soil standards to two significant figures.

15. Update the model to include calculation of soil to groundwater protective AW standards for both freshwater and estuarine/marine AW water use standards.

4.2 Changes to the Model, and related Protocols, for Consistency and Harmonization

As related to updating of the model, the ministry proposes to revise the CSST GPM [1] and related protocols to ensure consistency and harmonization between the various ministry protocols. The proposed changes are as follows.

1. Update CSR Protocols 2 [8] and 13 [9] in coordination with updating of the CSST model [1] to improve the overall usability of the protocols.

2. Evaluate leachate test methods for adoption in Protocol 2 [8] to allow for use of leaching tests for site-specific numerical soil standards calculation. Harmonize leaching tests between Protocols 2 [8] and 13 [9].

3. Adopt the Protocol 13 [9] Aquatic Life protection (AW) pathway mixing model for all water uses (AW, Drinking water (DW), irrigation water (IW) and livestock watering (LW) to ensure harmonization between use of the model to develop soil to groundwater standards and use of the model for the purposes of Protocol 13 [9].

4. As part of model updating, revise the maximum transport distance allowed in Protocol 2 [8] to 500 m for harmonization with Protocol 21 [10].

5. Clarify in the documentation for the proposed new modified model that, consistent with Technical Guidance 15 [11] and Protocol 13 [9], the AW water use standard is

applied at 10 m from the receiving environment (10 m from high water mark) for the AW pathway.

6. Related to the proposed new soil type in the model, under Protocol 2 [8], retain the maximum allowed linear velocity of 100 m/year and revise the minimum allowable velocity to 5 m/year.

7. In addition to those changes identified elsewhere in this document, harmonize the model defaults and input parameters between the proposed new and CCME, 2006 [12] models. At a minimum, harmonize the proposed new model with the CCME, 2006 [12] model in regard to: source dimensions, fraction of organic carbon, and bulk density.

8. In addition to those changes identified elsewhere in this document, harmonize the substance properties between the proposed new model and Protocol 13 using the US DOE RAIS database.

5. Other Issues - Next Cycle Revisions

Other potential updates to the model have been identified based on the SABCS [4] and other recommendations and the limited literature review conducted to date. However, these changes are not proposed for updating as part of the omnibus updating of the CSR standards for the stage 10 amendment to the Regulation, as the time and/or effort required for completion of, and stakeholder consultation on, these other issues cannot be accomplished in time available for the stage 10 amendment. Accordingly, these other issues are presented for consideration as part of the proposed future next cycle of revisions to the CSR standards.

The next cycle revisions (future considerations) related to the CSST GPM [1] and derivation of CSR Schedule 5 matrix soil to groundwater protection standards are summarized as follows:

1. Evaluate the potential for web-hosting of the proposed new GPM.

2. Evaluate opportunities for field determination/validation of distribution coefficient (K_d) values used in the GPM for various sites in the Province.

3. Evaluate incorporation of pore-water standards and leaching tests in the GPM.

4. Evaluate opportunities for field validation of partitioning coefficients and decay rates used in the GPM based on assessment of province-wide contaminated sites data.

5. Evaluate incorporation of the AW pathway transport assessment used in CCME, 2015 [16] for use in deriving matrix soil to groundwater standards for the protection of aquatic life (i.e., consider modification of the ten times AW dilution factor used in the GPM).

6. Following from item 5 above, evaluate possible incorporation of the CCME, 2015 [16] AW pathway transport assessment for use in setting the aquatic life protection water quality standards of CSR Schedule 6.

7. Conduct a sensitivity analysis of GPM biodegradation and sorption attenuation processes with respect to the extent of conservatism inherent in their use in calculating matrix soil standards.

8. For chlorinated solvents, undertake an evaluation of alternate approaches that may more effectively address concerns related to determination of whether biodegradation may occur and the concomitant potential for formation of toxic daughter products in groundwater.

9. Evaluate f_{oc} values for different hydrogeologic environments and assess whether the derivation of multiple soil standards based on f_{oc} ranges might improve or streamline the CSR regulatory regime for groundwater protection.

10. Evaluate development of recharge rates using the United States Army Corps of Engineers (US Army) Hydrologic Evaluation of Landfill Performance (HELP) code [24] or United States Geological Survey (USGS) VS2DT Solute Transport in Variably Saturated Porous Media code [25] along with BC climate zone data.

11. Evaluate existing and potential new constraints/limits to ensure appropriate conservatism of the GPM.

12. Evaluate the consistency achieved by, and feasibility of, incorporating changes to the GPM to address dilution due to infiltration occurring downgradient from the contaminant source zone.

13. Evaluate the practicability of, and need to, develop soil standards based on porewater to protect soil invertebrates.

14. Evaluate the practicability of, and need to, develop soil to groundwater standards to protect phreatophyte and non-phreatophyte plants.

15. Evaluate the practicability of, and need to, develop soil standards based on groundwater contaminant transport to surface water for the purposes of protecting wildlife surface water ingestion (i.e. wildlife drinking watering pathway).

Also as part of the next cycle revisions, as noted above, the initial literature review was limited due to the short timeframe available for the omnibus updating project. Accordingly, a more detailed literature review is proposed to be completed as part of the next cycle revisions. At this time, it is anticipated that the detailed review would consist of the models reviewed on a limited basis (as noted in section 3) in addition to, although not necessarily limited to, the following:

- US EPA Soil Screening Guidance (US EPA, 1996 [19]);
- US EPA 3MRA model (US EPA, 2003 [20]);
- Oregon State Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites (Oregon DEQ, 2003 [26]);
- Washington State Guidance for Remediation of Petroleum Contaminated Sites (Washington DoE, 2011 [27]); and
- New Jersey Remediation Standard N.J.A.C. 7:26D (New Jersey DEP, 2012 [28]).

Future detailed review may also be conducted of any new agency models or approaches developed for protection of water uses through setting/calculation of soil standards. The detailed review would also likely be limited to review of analytical models (non-numerical) given the relative ease with which analytical models may be coded for use in simple spreadsheet models and the relative difficulty for same, with numerical models.

6. References

[1] British Columbia. (1996). *Overview of Contaminated Sites Soil Task Group (CSST) Procedures for the Derivation of Soil Quality Matrix Standards for Contaminated Sites.* Ministry of Environment, Lands and Parks. January 31, 1996.

[2] British Columbia. (1996). *CSST Policy Decision Summary. Part I: Record of CSST Policy/Decision Issues Relating to the Derivation of Matrix Standards Based on Canadian Council of Ministers of the Environment Protocol and Site-Specific Objectives Documents and Part II: Record of CSST Policy/Decision Issues Relating to the Derivation of Matrix Standards Based on Novel CSST Procedures.* Ministry of Environment, Lands and Parks. January 24, 1996.

[3] British Columbia. (2014). *Contaminated Sites Regulation. B.C. Reg. 375/96*. A regulation under the *Environmental Management Act*.

[4] Science Advisory Board for Contaminated Sites in British Columbia. (2005). *Scientific Review of British Columbia CSST Soil Standards Derivation Protocol*. July 2005.

[5] Kool, J.B, Huyakorn, P.S., Sudicky, E.A., Saleem, Z.A. (1994). *A Composite Modeling Approach for Subsurface Transport of Degrading Contaminants from Land-Disposal Sites*. Journal of Contaminant Hydrology, 17. 1994.

[6] Domenico, P.A. (1987). *An Analytical Model for Multidimensional Transport of a Decaying Contaminant Species*. Journal of Hydrology, 91. 1987.

[7] United States Environmental Protection Agency. (1996). *BIOSCREEN, Natural Attenuation Decision Support System*. EPA/600/R-96/087. August, 1996.

[8] British Columbia. (1998). *Protocol 2 for Contaminated Sites. Site-Specific Numerical Soil Standards*. Ministry of Environment. February 11, 1998.

[9] British Columbia. (2008). *Protocol 13 for Contaminated Sites. Screening Level Risk Assessment*. Ministry of Environment. August 1, 2008.

[10] British Columbia. (2015). *Protocol 21 for Contaminated Sites. Water Use Determination. Version 1.0, Draft 9*. Ministry of Environment. 2015.

[11] British Columbia. (2013). *Technical Guidance 15 on Contaminated Sites. Concentration Limits for the Protection of Aquatic Receiving Environments*. Ministry of Environment. April 2013.

[12] Canadian Council of Ministers of the Environment. (2006). *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines.* CCME. 2006.

[13] Canadian Council of Ministers of the Environment. (2008). *Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil*. CCME. 2008.

[14] Science Advisory Board for Contaminated Sites in British Columbia. (2005). *Screening Level Risk Assessment, SLRA Level 1 and SLRA Level 2*. August 2005.

[15] Society of Contaminated Sites Approved Professionals of British Columbia. 2011. Drinking Water as a Factor in Soil Assessment, CSAP Technical Review #1103. Technical Guidance 6 Working Group 3. December, 2011.

[16] Canadian Council of Ministers of the Environment. (2015). *A Protocol for the Derivation of Groundwater Quality Guidelines for Use at Contaminated Sites*. CCME. 2015.

[17] Alberta. (2011). *Alberta Tier I Soil and Groundwater Remediation Guidelines*. Ministry of Environment and Sustainable Resource Development. 2014.

[18] Ontario. (2011). *Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act*. Ministry of the Environment. April 2011.

[19] United States Environmental Protection Agency. (1996). *Soil Screening Guidance: User's Guide, 2nd Edition. EPA/540R-96/018*. July 1996.

[20] United States Environmental Protection Agency. (2003). *Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment (3MRA)*. July 2003.

[21] Axiom Environmental Inc. (2011). *Proposed Values of Biodegradation Rate for Organic Chemicals for Use in the British Columbia CSST Model (draft).* March 2011.

[22] United States Department of Energy. (2015). *Risk Assessment Information System*. 2015.

[23] British Columbia. (2009). *Hazardous Waste Regulation. B.C. Reg. 63/88*. A regulation under the *Environmental Management Act*.

[24] United States Army Corps of Engineers. (1994). *Hydrologic Evaluation of Landfill Performance*. July 1994.

[25] United States Geological Survey. (1996). *VS2DT Solute Transport in Variably Saturated Porous Media*. July 1996.

[26] Oregon State. (2003). *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites*. Department of Environmental Quality. September 2003.

[27] Washington State. (2011). *Guidance for Remediation of Petroleum Contaminated Sites. Department of Ecology*. September 2011.

[28] New Jersey State. (2012). *Remediation Standard N.J.A.C. 7:26D*. May 2012.

[29] Sauvé, S., Manna, S., Turmel, M., Roy, A.G., Courchesne, F. (2003). *Solid-Solution Partitioning of Cd, Cu, Ni, Pb, and Zn in the Organic Horizons of a Forest Soil.* Environmental Science & Technology, 37. 2003.

[30] United States Environmental Protection Agency. (1996). *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods—SW846. Third Edition*. 1996.

[31] Australia. (1997). *Australian Standard 4439.2 – 1997, Wastes, sediments and contaminated soils. Part 2: Preparation of leachates – Zero headspace procedure*. Standards Australia. 1997.

[32] Australia. (1997). *Australian Standard 4439.3 – 1997, Wastes, sediments and contaminated soils. Part 3: Preparation of leachates – Bottle leaching procedure*. Standards Australia. 1997.

[33] American Society for Testing and Materials. (2015). *Standard Practice for Shake Extraction of Solid Waste with Water D-3987-12*. 2015.

[34] S.S. Papadopulos & Associates Inc. *BIOSCREEN-AT*.

[35] Health Canada. (2012). *Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment*. 2012.

[36]United States Environmental Protection Agency. (2015). *Region 9 Regional Screening Levels (PRGs)*. January 2015.

GS
Q:\EPD\EMB\General\CS Program\Standards & criteria\Omnibus Update 2015-16\June 19 2015 proposal papers to Jim\Final June 2015 Sch 5\Sch 5 Soil to GW stds\Final June 2015 Soil to GW stds proposal paper v4

Appendix A.

Science Advisory Board for Contaminated Sites in British Columbia (SABCS), 2005 [4, 14] and Other Stakeholder Recommendations Relating to Updating and Revising the CSST, 1996 [1] Groundwater Protection Model for Use in the Derivation of Matrix Soil to Groundwater Protection Standards; and the Decisions of the Ministry in Respect to SABCS and Other Stakeholders Recommendations.

Table A1.

SABCS, 2005 [4, 14] and Other Stakeholder Recommendations Relating to Updating and Revising the CSST, 1996 [1] Groundwater Protection Model for Use in the Derivation of Matrix Soil to Groundwater Protection Standards; and the Decisions of the Ministry in Respect to SABCS and Other Stakeholders Recommendations.