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

Line Item	Issue	Existing Protocols			SABCS 2005/Other Recommendations	Comments/Discussion	Proposed Changes to CSST Protocol Groundwater Protection Model*	Proposed Changes to Protocol 13 (SLRA) for harmonization with CSST Protocol.
		CSST (1996)	CCME (2006)	Protocol 13 (2008)				
1	General – model concept and harmonization	Model concept is to calculate soil standards that are protective of water uses. Allowable soil standard (concentration) is back-calculated based on the applicable water use standard at the receptor. Backward calculation is utilized (receptor to source).	Same concept as CSST (1996).	Model concept is to determine if predicted or actual groundwater concentrations meet the applicable water use standard at the receptor. Forward calculation is utilized (source to receptor).	Harmonize between ministry/agency models, in so far as possible.	The CSST and CCME models were developed or initiated at similar time periods but have some differences in model formulation and application. Protocol 13 was developed at a later time period and uses similar transport components as the CSST/CCME models but also contains some differences. The CSST model may also be used for calculation of site-specific soil standards under Protocol 2. An overarching objective of the omnibus standards updating project is to harmonize the model formulations/characteristics between the ministry's CSST protocol and Protocol 13. A companion objective is for harmonization between the CSST and CCME protocols, in so far as possible. As the model may be used under Protocol 2, a related objective of the omnibus project is to revise and update Protocol 2 to make it more practical, user friendly and of greater utility in contaminated sites assessment. Similar revision and updating of Protocol 13 is also envisaged.	As detailed below.	As detailed below.
2	Soil Types	Single soil type (default) based on typical soil properties	Two soil types consisting of: (i) coarse grained –	Same as CSST (1996).	Develop soil to groundwater pathway standards for two soil types	It is acknowledged that a single soil type is not representative of the variation in soil conditions across	Modify the existing default soil type in the CSST protocol to be	Adopt the revised CSST protocol default soil type once

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		for Fraser River Sediments (FRS) in the Lower Mainland region of BC. Use of site-specific soil properties allowed under Protocol 2.	soils which contain greater than 50% by mass, particles greater than 75 µm mean diameter (D_{50}>75 µm); and (ii) fine-grained – soils which contain greater than 50% by mass, soil particles less than 75 µm mean diameter D_{50}<75 µm).	Use of alternate soil properties allowed.	to accommodate the variation in soil conditions in BC and to harmonize with CCME.	BC. Also, by design, a single soil type should be conservative for the purposes of calculation of numerical (matrix) soil standards. However, it is proposed to retain use of a single soil type, subject to modification as described below, due to the uncertainties with soil description and classification based on the wide range in heterogeneous soil conditions throughout BC. Use of a single soil type also simplifies the CSR matrix schedules. With respect to the conservatism of the FRS soil type, in comparison to the CCME coarse-grained soil type, the CSST FRS is slightly coarser with a groundwater velocity over two times higher than CCME. Accordingly, as part of the overarching harmonization objective of the omnibus project, it is proposed to utilize a revised soil type as the default soil type in the CSST model which is more consistent with the CCME coarse-grained soil type and which is likely more broadly representative of coarse-grained soil conditions in BC. However, outright adoption of the CCME coarse-grained soil type is not proposed as the hydraulic gradient and hydraulic conductivities utilized by CCME are not consistent with typical BC conditions. Other soil types may be evaluated using Protocol 2.	more consistent and for harmonization with the CCME coarse-grained soil type (similar groundwater velocity although with more BC-specific hydraulic gradient and conductivity values) and be more broadly representative of coarse-grained soil conditions in BC. Retain functionality to allow for use of site-specific soil properties under Protocol 2.	developed. Retain functionality to allow for selection of alternate soil properties under Protocol 13.

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3	Model framework	Multi-component analytical model consisting of (i) partitioning of contaminants (ii) unsaturated zone transport (iii) groundwater mixing, and (iv) saturated zone transport. Applied for organic and inorganic substances.	Similar to CSST (1996) except that the model is only applied for organic substances. Transport of inorganic substances is evaluated on a site-specific basis. The model also includes two soil types as noted above. Other differences as noted below.	Similar to CSST (1996). Differences as noted below.	1. Retain a multi-component analytical model consisting of (i) unsaturated zone partitioning, (ii) groundwater mixing, and (iii) saturated zone transport for all receptor scenarios; however, consider refinements to the model and input parameters as summarized below.	Agreed. The overall model framework is consistent with that in use in other jurisdictions.	Retain existing four component model. Retain the spreadsheet format with upgrade of the graphical user interface, include greater transparency in parameter selection/input and substance properties, and prepare updated documentation. Future consideration – evaluate potential for web-hosting of the model.	Incorporate CSST framework elements in Protocol 13, where possible. Incorporate the transport prediction component of Protocol 13 as a separate module in the CSST Groundwater Protection Model for ease of calculation.
4	Partitioning coefficients for inorganic substances (K_d values)	CSST (1996) distribution coefficient values. Selected from EPA SSG or developed using MINTEQ2. Isotherm for Pb is same as Cu isotherm.	Model is not applied for inorganic substances.	Partitioning of inorganic substances is not included in unsaturated zone. Leaching tests used instead.	8. For derivation of soil standards, adopt the partition coefficients recommended by USEPA (1996b) for the following metals: antimony; arsenic(III) (no change in soil standards); barium; beryllium; cadmium (increase in soil standards); chromium(III) (increase in soil standards); chromium (VI) (no change in soil standards); cyanide; nickel; selenium; silver; thallium; vanadium; and, zinc (decrease in soil standards, in most cases). It is noted that antimony, barium, beryllium, mercury, nickel, selenium, silver, thallium and vanadium are not	Conceptual agreement. Differing recommendations were provided by SABCS between the SABCS 2005 Golder CSST groundwater model review and SABCS 2005 SRA-2. Partitioning coefficients (K_d values) were recommended to be retained in the CSST model but not recommended to be included in SRA-2. The SABCS Golder CSST review report also included the following comment from Uli Mayer on the use of K_d values for standards development: “If the “USEPA model” [deterministic partitioning models] is chosen to derive soil standards in BC, I believe that it is necessary to ensure that the K_d values used to determine the soil standards are indeed conservative...to make the approach defensible. From this point of view,	For simplicity and consistency in matrix numerical soil standards calculation, adopt the EPA SSG partition coefficients for existing and proposed matrix numerical substances except use internally developed K_d values for barium, chloride, mercury and sodium. At the same time, prescribe a leaching test in Protocol 2 so that leaching tests may be used for calculation of site-specific soil standards. [Net changes to soil standards:	None. Retain use of leaching tests for inorganic substances as this is consistent with a site-specific/risk-based approach.

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					currently included in the Schedule 5 matrix standards. The implications for use of USEPA partition coefficients to derive pH dependent standards for these metals should be further evaluated before any changes to the CSR standards are considered. Such an evaluation goes beyond the scope of this report. The USEPA K_d's for mercury are not recommended since empirical data indicates they are overly conservative and do not correctly predict the influence of pH on K_d.	I welcome the field validation approach (field determination/validation of K_d values for various sites in BC) suggested in the current Golder report...However, without such a validation effort..., I cannot see how the approach is scientifically defensible, and I don't think it should be adopted in the long term...If such a validation study cannot be undertaken, I suggest that it is better to use an approach that derives conservative (lower 95% prediction interval) K_d's from generic field data compilations such as that by Sauve et al., 2003 [29]. Alternatively, a leach test procedure in combination with aqueous standards could be used, as suggested in the current Golder report.	As, Ba, Cl-, Cr(+6), Hg, Na+ – no change Cr(+3) – increase Cd/Zn – increase/decrease] Future consideration – evaluate opportunities for field determination/validation of K_d values for various sites in BC.	
5	pH-dependent K_d isotherms for lead and copper	pH-dependent K_d isotherm for lead is included. Isotherm is same as copper isotherm.	Model is not applied for inorganic substances.	Partitioning of inorganic substances is not included in unsaturated zone. Leaching tests used instead.	9. Develop an isotherm for lead using data in the 3MRA database, assuming iron oxide and organic matter input values identical to USEPA SSL defaults. An interim K_d isotherm was developed using 3MRA for "mid-range" iron oxide and organic matter conditions, with an iron oxide concentration of 0.05 wt% and organic matter concentration of 0.11 wt%. 10. Using a similar approach to the 3MRA modeling effort, employ the	Agreed.	Develop and incorporate lead and copper isotherms using 3MRA database and EPA SSG default input values. [Changes to soil standards dependent on isotherms as developed].	None. Retain use of leaching tests for inorganic substances as this is consistent with a site-specific/risk-based approach.

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					MINTEQA2 thermodynamic database to develop an isotherm for copper, assuming iron oxide and organic matter input values identical to USEPA SSL defaults.			
6	Pore-water standards and leaching tests for inorganic substances	Not included. Use of leaching tests available in Protocol 2 although not activated pending development of a leachate test method.	Not included. Transport of inorganic substances is evaluated on a site-specific basis.	Leaching tests for inorganic substances included (SPLP and TCLP).	11. Consideration should be given to a regulatory framework that includes pore-water standards and a protocol where the results of leaching tests can be compared to pore-water standards. For metals, pore-water standards and leaching tests would avoid some of the scientific issues and uncertainty associated with the K_d approach.	Agree with modification. The availability of pore-water standards is limited in literature and would require additional consideration. Use of leaching tests is already available in Protocol 2 pending specification of a leachate test method. Available methods in literature include the SPLP, TCLP and MEP (US EPA SW846)[30]. Other methods include the ASLP [31,32] (Australian version of TCLP) and ASTM D3987-12 [33] (shake flask extraction). Both the SPLP and TCLP are currently used in Protocol 13 depending on the soil pH. The SPLP simulates acid rain leaching. The TCLP simulates organic acid landfill leaching. The MEP adds a time component to the TCLP (repeated leaching) resulting in a more aggressive test. The ASTM shake flask extraction uses deionized water and is more suitable for laboratory comparison of leachate analyses or to assess the interaction of the extractant with the buffering capacity of the soil. The ASLP is a more efficient (with respect to extraction) version of the TCLP as it is based on a 2 mm maximum particle size but the test is	None. Evaluate which leachate test method(s) to apply in Protocol 2 when the protocol is updated. Future consideration – evaluate incorporation of pore-water standards and leaching tests in the CSST model.	Harmonize leachate test method(s) with Protocol 2, once finalized.

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						not widely used in contaminated sites assessment in North America. It is proposed to evaluate which leachate test method(s) to apply when Protocol 2 is updated.		
7	Field-based evaluation of partitioning coefficients for inorganic substances	Fixed K_d values dependent on soil pH.	Partitioning of inorganic substances is not included.	Partitioning of inorganic substances is not included. Leaching tests used instead.	12. To gain further insight on the predictive capability of the metals partitioning model, it is recommended that soil and near-contaminated source groundwater quality data from contaminated sites in British Columbia be evaluated to provide for field-based estimates of groundwater fate and transport, and indirectly partitioning behaviour.	Agree with modification. Such an exercise would require sufficient budgeting and liaison/cooperation with stakeholders for compilation and assessment of suitable investigation data and site-specific characteristics. Evaluate such an opportunity as a future consideration and as part of ranking of priority items within the ministry and stakeholders.	None. Future consideration – evaluate opportunity for field validation of partitioning coefficients and decay rates based on province-wide contaminated sites data assessment.	None at present.
8	Unsaturated zone transport	Included but not active in calculation of matrix numerical soil standards as the default model scenario assumes contamination extends to the water table (unsaturated zone transport is effectively “turned off” in this configuration). Developed based on Kool et al, 1994. May be utilized for calculation of site-specific numerical	Included but not active in calculation of Tier I (generic) soil quality guidelines. May be activated for calculation of Tier II (site-specific) or Tier III (risk-based) guidelines.	Not included.	2. Since unsaturated zone transport does not affect the calculation of soil standards based on the current model scenario; for clarity, eliminate the unsaturated zone component from the CSST protocol, subject to findings of on-going evaluation of unsaturated zone transport by SAB (no change in standards).	Agreed for the purposes of calculation of matrix numerical soil standards. Not agreed for the purposes of calculation of site-specific numerical soil standards under Protocol 2. Unsaturated zone transport was identified to be of significant benefit for site-specific standards calculation as following from the 2011 CSAP Technical Guidance 6 Technical Working Group 3 deliberations and recommendations.	Since there is only one model version, retain unsaturated zone transport component in model to allow for calculation of site-specific soil standards under Protocol 2. Retain default model scenario that unsaturated zone transport is not active for calculation of matrix numerical soil standards. [No change to soil standards].	Incorporate unsaturated zone transport.

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		soil standards using Protocol 2.						
9	Mixing model	CSST (1996) mixing equation. Dilution factor is 3.31 due to mixing.	Same as CSST (1996).	Modified mixing equation developed by SABCS for AW pathway. Considered to be more appropriate for shorter transport distances. Dilution factor is 3.43 due to mixing for AW pathway. Dilution factor is 20 for DW, IW and LW pathways.	7. Adopt the revised SRA-2 groundwater mixing model for derivation of soil standards (slight increase in the standards). Adopting the USEPA DAF of 20 for the receptor well scenario is not recommended at this time.	Agreed. Development of matrix numerical and site-specific soil standards are based on shorter transport distances, therefore, the SLRA AW pathway mixing equation is more appropriate for these cases. Use of a DAF of 20 for the DW pathway is not considered sufficiently conservative for development of matrix numerical soil standards.	Adopt the SLRA AW pathway mixing model for all water uses. [Slight increase in soil standards due to slightly higher dilution factor].	Delete the dilution factors for DW, IW and LW pathways and adopt the SLRA AW pathway groundwater mixing model for all water uses.
10	Saturated zone transport - model solution form	Domenico (1987) 2-D transient solution. Transport time is 2200 years which is effectively steady-state for most substances (except for Cd, Cu, Pb and Zn due to high retardation values for these substances at higher soil pH values).	CSST (1996) saturated zone transport model but with a transport time of 100 years. Considered to be steady-state for most substances (organics). Applied only to AW pathway.	Domenico (1987) 2-D steady-state solution for organics and inorganics. However, retardation is effectively turned off for inorganic substances due to steady-state solution form.	16. Consideration should be given to adopting the SRA-2 steady state analytical model for saturated zone transport since the intent of the CSST model was to simulate steady state conditions and since dispersion does not affect the model simulations for a transport distance of 10 m (decrease in soil standards in some cases).	Agreed on the form of the transport solution. A steady-state solution is more conservative and consistent with previous practice as the CSST (1996) model was essentially a steady-state approach. A steady-state formulation is also used in the 2008 CCME CWS PHCs model and in the Alberta ESRD model). Not agreed on the dimensionality of the transport solution. The initial SABCS SRA-2 recommendation was for a 1-D (Bear) steady-state solution. However, the 2-D Domenico (1987) steady-state solution was implemented in Protocol 13. The 2-D solution form incorporates transverse dispersion which is a scientifically defensible attenuation process. The solution is also well documented in literature and is in use by many other	Adopt the Domenico (1987) 2-D steady-state saturated zone transport model to harmonize with Protocol 13. [No changes for most soil standards except for decrease in standards for Cd, Cu, Pb and Zn at higher soil pH values as these substances were not at steady-state in CSST (1996) saturated zone transport transient solution form].	None - Domenico (1987) 2-D steady-state solution already utilized.

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						jurisdictions.		
11	Saturated zone transport – accuracy of model solution form	Domenico (1987) 2-D analytical saturated transport solution is not an exact solution.	Same as CSST (1996).	Same as CSST (1996).	Consider replacing the Domenico approximate analytical saturated transport solution with an exact solution.	This issue is well known in the literature. The Domenico analytical solution is not exact and that errors can be introduced if high longitudinal dispersivities are used. In consideration of this, an exact three-dimensional analytical solution has been developed by S.S. Papadopulos & Associates, Inc. (ATRANS as incorporated in BIOSCREEN-AT)[34]. The ATRANS solution is applied using a patch boundary condition within a semi-infinite aquifer. Although not exact, it is known that there is only limited error in the Domenico solution for predicting concentrations along the plume centreline for steady-state conditions and where dispersivities are constrained to lower values. The CSST model formulation is developed with such prediction/constraints. The Domenico solution is also in use by many other jurisdictions.	Retain use of the Domenico (1987) 2-D analytical solution with the current prediction/constraints and for consistency with CCME, Protocol 13 and other jurisdictions.	None - Domenico (1987) 2-D steady-state solution already utilized.
12	Saturated zone transport – transport distance (x)	Default transport distance is 10 m. Maximum transport distance allowed in Protocol 2 is 100 m.	Default transport distance is 10 m for AW pathway. No transport for DW, IW and LW pathways.	Maximum transport distance is 1,000 m. Where DW applies, allowable transport distance is constrained to the property boundary.	15. Retain the 10 m separation distance between the contamination source and the receptor for the saturated zone model for all water uses.	Agreed. Differing transport distances are used between Protocol 2 and Protocol 13. With the introduction of Protocol 21 (Water Use Determination), the water use pathways are deemed to apply where receptors are located within 500 m of a contaminated site. Harmonization between the various	None for matrix numerical soil standards. Revise the maximum transport distance allowed in Protocol 2 to 500 m consistent with Protocol 21.	Revise the maximum transport distance allowed in Protocol 13 to 500 m for harmonization with Protocols 2 and 21.

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						protocols would be advantageous for consistency in application.		
13	Saturated zone transport – receptor and receptor location	For the DW, IW and LW pathways, the receptor is a water well user. The receptor is located at the transport distance. For the AW pathway, the receptor is an aquatic receiving environment. Following from Technical Guidance 15, the receptor is deemed located at an offset distance of 10 m from the receiving environment.	For the DW, IW and LW pathways, the receptor is located at the edge of the source area (no transport distance). For the AW pathway, the receptor is located at the transport distance.	For the DW pathway, the receptor is a water well user or the property boundary, whichever is lesser (for protection of groundwater for potential future drinking water use). For the IW and LW pathways, the receptor is a water well user. For the AW pathway, the receptor is located at an offset distance of 10 m from the receiving environment (10 m from high water mark).	Clarify the receptors and receptor locations for the purposes of development of matrix numerical soil standards.	The transport distances and receptors applied in the CSST model differ from CCME but are considered reasonable and realistic. Following the introduction of Technical Guidance 15, application of the receptor boundary for the AW pathway was clarified (10 m from high water mark). This issue should also be clarified in the CSST model documentation for consistency with the guidance and Protocol 13.	Clarify in the CSST documentation that, consistent with Technical Guidance 15 and Protocol 13, the AW water use standard is applied at 10 m from the receiving environment (10 m from high water mark) for the AW pathway.	None.
14	Saturated zone transport – water use standards and dilution factors applied at the receptor	For the DW, IW and LW pathways, no dilution factor is applied (Schedule 6 DW, IW and LW standards are used at the receptor). For the AW pathway, no additional dilution factor is applied (Schedule 6 AW standard (which already incorporates	No dilution factor is applied for any water use.	Same as CSST.	20. Retain a dilution factor of ten between groundwater and surface water criteria [10 times dilution factor incorporated in Schedule 6 AW standard].	Agreed. The policy basis for the 10 times dilution factor is noted in Technical Guidance 15. The factor is applied based on the assumption of the availability for dilution of groundwater prior to discharge to the receiving environment. The 10 times factor was developed as part of the initial CSST model development with model calibration to Fraser River sediments. The factor was also based on the draft 2004 USEPA SSG guidance which identified a DAF of 10 as generally	None. Future consideration – evaluate incorporation of the AW pathway transport assessment used in CCME 2015 for use in development of matrix numerical soil standards for the AW pathway (replacement of the CSST 10 times AW dilution factor).	None.

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		10 times dilution) is applied at an offset distance of 10 m from the receiving environment).				conservative for dilution in groundwater. As part of recent groundwater guidelines development for contaminated sites, CCME (CCME, 2015) has recently introduced an alternate concept for development of Tier I AW guidelines. Instead of adopting a dilution factor approach, similar to CSST, the CCME concept involves back-calculation of an acceptable groundwater concentration as based on saturated zone transport prediction to a receiving environment (predict allowable concentration in groundwater to meet the applicable water quality guideline at the receptor). This concept is essentially the same as the saturated zone transport component in the CSST model. This concept should be explored further as part of consideration for adoption. Based on the limited timeframe of the omnibus standards updating project, it is proposed to evaluate this issue as a future consideration.	Future consideration – following from the above, evaluate incorporation of the CCME 2015 AW pathway transport assessment for use in setting of AW standards in Schedule 6.	
15	Saturated zone transport – decay values for organic substances	1995 values for BETX, naphthalene, benzo[a]pyrene, PCP, PCE and TCE. Rates are based on 50% of low anaerobic biodegradation rate.	Adopted from Health Canada 2012 [35] and/or CCME CWS PHCs 2008.	2004 values for BETX, naphthalene, and pyrene. Rates based on 25th percentile anaerobic biodegradation rate. No values for benzo[a]pyrene (insoluble), PCP (ionizing organic),	17. A comparison of literature half-lives for biodegradation suggests that some of the CSST model half-lives assumed for organic chemicals may not be conservative. A more in-depth review of decay constants should be conducted. When complete, representative	Agreed. A literature review was commissioned for this purpose. The review was conducted by Axiom Environmental Inc. and included recommendations for updated biodegradation rates for use in the CSST model.	Adopt new biodegradation rates as provided in Axiom Environmental Inc., 2011. New decay rates are generally the lower of i) the 25th percentile of all studies or ii) lowest of high quality studies. Circulate the document	Use same decay rates as CSST for harmonization.

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				PCE and TCE (decay may not proceed).	values based upon this review should be selected for input into the model. For consistency, identical parameters should be selected for both the groundwater model used to back-calculate CSR soil standard and SRA-2.		for stakeholder review as part of the omnibus standards updating project. [Changes to soil standards will be dependent on the final updated biodegradation rates. However, on a preliminary basis, the calculated soil standards are likely to decrease as the proposed new biodegradation rates are generally lower than current CSST rates].	
16	Saturated zone transport – modelling of decay and sorption for organic substances	Decay and sorption active for organic substances in saturated zone.	Decay and sorption active for organic substances in saturated zone.	Decay and sorption active for organic substances in saturated zone.	18. The combination of decay (half-life) and sorption (K_{oc}, f_{oc}) have a significant effect on model-predicted organic groundwater concentrations at 10 m from the source. Once representative half-lives have been selected, it is recommended that the steady state model be run to evaluate the effect of these two parameters. The simulation results, together with the mixing model results, should be used to derive example soil standards (i.e., similar to metals Table 2.3 described earlier). The results should be carefully assessed to evaluate whether incorporation of these fate	Agreed with modification. Given the limited timeframe for the omnibus standards updating project, and the effort anticipated for such a sensitivity analysis, the sensitivity analysis is proposed to be conducted in a future standards updating project.	None. Future consideration - conduct sensitivity analysis of biodegradation and sorption attenuation processes with respect to conservativeness for use as part of matrix numerical soil standards calculation.	None. Harmonize with CSST protocol in future, as may be necessary.

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					and transport processes is reasonable for generic soil standard development purposes.			
17	Saturated zone transport – decay rates for potentially recalcitrant substances and toxic daughter products (PCE, TCE)	Substances included in CSST with decay rates.	Substances included with decay rates.	Substances included in SLRA but without decay rates.	SABCS SRA-2 recommendation was to not allow decay for potentially recalcitrant substances due to concerns with whether decay proceeds and formation of more toxic daughter products.	Allowance for decay of PCE and TCE differs between CSST model and Protocol 13. As recommended by SABCS, decay was not included in Protocol 13 as degradation may not proceed under certain site conditions (absence of co-substrate in oxidative co-metabolism of TCE or electron donor in reductive dechlorination of PCE and TCE). A companion concern is that where decay does occur, degradation may result in more toxic daughter products (vinyl chloride) which is not captured in the soil standard calculation for PCE and TCE. It is proposed to not allow decay in the CSST model for PCE and TCE to harmonize with Protocol 13. For future considerations, an assessment should be undertaken of alternate policies that may be applied to address the concerns identified above (such as the 10% rule employed by Ontario MoE).	Eliminate the biodegradation rates for PCE and TCE in the CSST model to harmonize with Protocol 13. Future consideration – undertake an evaluation of alternate policies that may be applied to address the concerns relating to establishing the conditions under which biodegradation may proceed and concomitant potential for formation of toxic daughter products.	None.
18	Saturated zone transport – average linear velocity ($v=Ki/n_e$)	Default linear velocity value is based on typical value for Fraser River Sediments. Default value is 63 m/yr (Darcy flux is 12.6 m/yr). Minimum velocity	Default linear velocity values are: (i) coarse-grained - 25 m/yr (Darcy flux is 9 m/yr); and (ii) fine-grained - 2 m/yr (Darcy flux is 0.9 m/yr).	SLRA value is based on any potential site in BC. Minimum linear velocity allowable is 5 m/yr.	SABCS SRA-2 recommendation was for a minimum average linear velocity of 5 m/yr to address uncertainties with respect to heterogeneity/scale effects in low permeability environments and extrapolation of near site	As part of moving towards a default soil type that is more consistent with the CCME coarse-grained soil type (as per above), revise the default average linear velocity to be more in line with the corresponding CCME average linear velocity. The minimum allowable velocities should also be harmonized between	Develop a default groundwater linear velocity to be more consistent with the CCME coarse-grained soil type for closer alignment with CCME soil properties. [Increase in soil	None.

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		allowable under Protocol 2 is 25 m/yr (Darcy flux is 5 m/yr).			data to longer transport distances.	Protocols 2 and 13.	standards for organic substances in coarse-grained soils due to reduced velocities which allow for greater opportunity for biodegradation]. Under Protocol 2, retain maximum linear velocity allowable of 100 m/yr. Revise minimum allowable velocity to 5 m/yr for harmonization with Protocol 13.	
19	Distance to receptor ranges	Default transport distance of 10 m. Site-specific values allowed in Protocol 2.	Default transport distances dependent on water uses.	Transport distances are dependent on water uses.	Incorporate distance to receptor ranges in matrices or as lookup tables. Suggested distances include 10, 50, 100, 150, 300, and 500 m.	Not Agreed at this time. Incorporation of distance to receptor ranges may not be conservative for calculation of matrix numerical soil standards due to uncertainties in definition of the source area and the potential for heterogeneity at greater distances from the source area. Incorporation of distance ranges would also add greater complexity to the CSR schedules. In addition, this functionality is already available in Protocol 2. Accordingly, it is proposed to retain calculation of matrix soil standards at the default 10 m transport distance only.	None. Retain distance to receptor functionality in Protocol 2.	Not applicable – Protocol 13 allows for variation in distance to receptor, dependent on applicable water use.
20	K_{oc} values for non-ionizing organics	CSST (1996) K_{oc} values.	Adopted from Health Canada 2012.	Parameter values are from US EPA Region 9 Superfund PRGs [36], US DOE RAIS, and CCME CWS for PHCs.	3. Adopt the K_{oc} values for non-ionizing organics listed in SRA-2 Appendix C, Table C-1. It is noted that for several compounds, the K_{oc} values proposed by SABCS in the SRA-2 report are significantly different	Agreement to standardize substance properties database selection. Current ministry default is the RAIS database.	Use RAIS EPI Exp database for K_{oc} values (but check alternate sources for ethylbenzene K_{oc} due to large variation between RAIS EPI and existing CSST 1996 values).	Modify to use same values as CSST.

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					than the CSST values. The source of most SRA-2 K_{oc} values are those given in USEPA (1996).		[Changes to soil standards are substance specific].	
21	pH-dependent K_{oc} isotherm for PCP	CSST (1996) K_{oc} isotherm for PCP.	Ionizing organic substances may be considered where only the non-dissociated form is sorbed appreciably.	PCP as an ionizing organic substance is precluded from assessment in Protocol 13. Intent was to include at a future date.	4. Adopt the pH-dependent K_{oc} isotherm for pentachlorophenol derived by SAB, as documented in SRA-2 (slight decrease in soil standards).	Agreed. Use SABCS-derived K_{oc} isotherm for pentachlorophenol to update model substance properties.	Adopt the pH-dependent K_{oc} isotherm for pentachlorophenol as documented in SRA-2. [Decrease in soil standards].	Use same K_{oc} isotherms to harmonize with CSST.
22	pH-dependent K_{oc} isotherms for other ionizing organic substances	Only PCP is included as an ionizing organic in model.	Ionizing organic substances may be considered where only the non-dissociated form is sorbed appreciably.	Ionizing organic substances not included.	Incorporate variable soil pH ranges for ionizing organics (with pH dependent Koc's).	Agreed. Soil pH/ K_{oc} relationships are already included in the model for PCP. Incorporate for other ionizing substances, time and data permitting.	Incorporate variable soil pH ranges for ionizing organic substances where sufficient soil pH-K_{oc} relationship data is available, time permitting.	Use same K_{oc} isotherms to harmonize with CSST.
23	Unsaturated zone dry bulk density value	Default dry bulk density value is 1.74 g/cm^3.	Default dry bulk density values are: (i) coarse-grained - 1.7 g/cm^3; and (ii) fine-grained - 1.4 g/cm^3.	Default dry bulk density value is 1.7 g/cm^3.	5. Revise the unsaturated zone bulk dry density to 1.7 g/cm^3 input into the organic chemical partitioning equation, consistent with the value assumed by CCME (slight increase in the soil standards).	Agreed. Harmonize with CCME.	Adopt the recommended unsaturated zone dry bulk density value of 1.7 g/cm^3. [Slight increase in soil standards].	None - recommended dry bulk density value already utilized.
24	Fraction of organic carbon	Default f_{oc} value is 0.006. Use of site-specific f_{oc} values allowed in Protocol 2.	Default f_{oc} value is 0.005 (both coarse-grained and fine-grained soil types).	Same default f_{oc} value as CSST (1996). Use of alternate f_{oc} values allowed.	6. Consideration could be given to adjusting the fraction of organic carbon used for the organic chemical partitioning equation; however, further evaluation of this parameter for different hydrogeologic environments is recommended before any	Agree with modification. Intent is to harmonize with CCME in so far as possible. Also, the opportunity to use site-specific f_{oc}, values is already available under Protocol 2. Recommendations pertaining to evaluation of f_{oc} values for different hydrogeologic environments and derivation of multiple soil standards based on f_{oc} ranges accepted in	Adopt CCME default f_{oc} value for harmonization with CCME. Use of site-specific f_{oc} values allowed in Protocol 2. [Slight decrease to soil standards due to reduced partitioning].	Adopt CCME default f_{oc} value. Use of alternate f_{oc} values allowed in Protocol 13.

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					changes are made. Since partitioning is sensitive to f_{oc}, an alternative would be to develop multiple soil standards based on f_{oc} ranges and to provide the option for testing of site soil samples for f_{oc}.	principle for future consideration.	Future consideration – evaluate f_{oc} values for different hydrogeologic environments with derivation of multiple soil standards based on f_{oc} ranges.	
25	Infiltration rate	Default infiltration rate of 0.55 m/yr representative of the Lower Mainland region of BC. Use of site-specific infiltration rates allowed in Protocol 2.	Default infiltration rates are: (i) coarse-grained - 0.28 m/yr; and (ii) fine-grained - 0.20 m/yr.	Same default (fixed) infiltration rate as CSST (1996). Use of alternate rates allowed.	13. At this time, no change to the infiltration rate used to calculate groundwater mixing is proposed. However, consideration should be given to more scientifically-based estimation of the recharge rate. This could consist of use of models such as HELP and VS2DT and inputs corresponding to several climatic zones within BC.	Agreed with modification. Intent is to harmonize with CCME in so far as possible. The CCME infiltration rate for coarse-grained soil is lower than the current CSST value. However, the current CSST value is considered more representative of the Lower Mainland region of BC. Infiltration rates may be varied on a site-specific basis using Protocol 2. Recommendations pertaining to development of recharge rates using HELP/VS2DT and BC climate zone data accepted in principle for future consideration.	None - Retain CSST (1996) infiltration rate. Use of site-specific infiltration rates allowed in Protocol 2. Future consideration – evaluate development of recharge rates using HELP/VS2DT and BC climate zone data.	None. Use of alternate infiltration rates allowed in Protocol 13.
26	Source length dimension (X)	Default source length is 5 m. Use of unconstrained site-specific values allowed in Protocol 2.	Default source length is 10 m.	Unconstrained source dimensions allowed.	14. It is recommended that a contaminated site source length of 10 m be adopted for the groundwater mixing model, consistent with the CCME protocol (slight increase in the soil standards).	Agreed for harmonization with CCME. Unconstrained values allowed in Protocol 2.	Revise the default contaminated site source length value to 10 m for harmonization with CCME. [Slight increase in soil standards].	None - unconstrained source dimensions allowed.
27	Harmonization of default and input parameters between models.	Model includes prescribed source dimensions and soil and groundwater properties. Defaults and some	Similar default and input parameters as CSST (1996). Defaults and some input parameters may be modified using	Similar default and input parameters as CSST (1996) although alternate values may be used.	Following from above, harmonize model defaults and input parameters between the CSST, CCME and SLRA protocols, in so far as possible.	Harmonization is proposed to be completed for: • source dimensions (X,Y,Z); • fraction of organic carbon (f_{oc}); and, • bulk density (ρ_b).	In addition to those changes described above, harmonize the model defaults and input parameters between the CSST and CCME models, in so far as	Harmonize with CSST model as part of standards updating.

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		input parameters may be modified using site-specific values under Protocol 2.	under Tier II/III approaches.			Harmonization of other model components/parameters is as noted elsewhere in this document.	possible.	
28	Harmonization of model substance properties (Henry's constant, K_{oc}, solubility, etc.)	Substance properties from various literature sources.	Substance properties from various literature sources.	Substance properties from various literature sources which differ from CSST (1996).	Following from above, harmonize substance properties between the CSST and SLRA protocols and with CCME protocol, in so far as possible.	Some substance properties differ between CSST and Protocol 13. The ministry's current primary reference source is the US DOE RAIS database.	In addition to those changes described above, harmonize substance properties between the CSST and SLRA protocols using the RAIS database. Use RAIS EPI Exp values for Henry's constant (H'). Adopt the EPI solubility values as well (but check alternate sources for PCP solubility due to large variation between RAIS EPI and existing CSST 1996 values). [Changes to soil standards are substance specific].	Use same substance properties to harmonize with CSST model.
29	Soil standard solubility constraint – soil standard calculation	Included. Calculation of a soil standard is not possible where the predicted leachate concentration from partitioning exceeds the solubility constraint.	Included as a management consideration.	Not included as transport calculations are based on measured leachate concentrations or actual groundwater concentrations and forward calculation is used.	19. The CSST protocol should be revised to include a check based on solubility considerations assuming a single chemical is present (no co-solubility) effects. If the acceptable pore-water concentration at the contamination source exceeds the pure-chemical solubility, then no soil standard would be possible for that chemical.	Agree with modification. This functionality is already included in the model in that a back-calculated leachate concentration which exceeds the solubility constraint for a substance reports as "Leachate concentration at source is greater than solubility of contaminant. Soil standard will be shaded red. Click on Help for more information". Following this statement, "NS" (no standard) and red shading are reported for the respective worksheet soil standard cell. The issue, however, is not discussed in	Update the help file information so that the solubility check limitation is more transparent to the user. Also, report the calculated soil standard at the prescribed solubility limit instead of reporting "NS" which is of limited information to the user. [No change to magnitude of soil standards.	None necessary.

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						the help file information. Also, reporting of "NS" provides limited information to the user. The functioning of the solubility constraint should be made more transparent to the user. In addition, to enhance model functionality, it would be advantageous to "cap" and report the soil standard representative of a leachate concentration equal to the prescribed solubility limit instead of reporting "NS".	Proposed change is for improved model functionality].	
30	Soil standard solubility constraint – specification of solubility constraint	Solubility constraint is based on the pure-phase substance solubility.	Management consideration is based on the pure-phase substance solubility.	Not applicable as per above.	As per above, SABCS 2005 recommendation is that the solubility constraint should be based on the pure-phase substance solubility.	Not agreed. Reliance on the pure-phase solubility as a solubility constraint may not be conservative in consideration of co-solubility effects and that mixtures of contaminants are typically encountered at contaminated sites. To address this potential non-conservativeness, effective solubilities may be utilized or a reduction factor may be applied to the pure-phase solubility. Reduction factors may consist of 50% of pure-phase solubility for non-DNAPL substances and 10% of pure-phase solubility for DNAPL substances. Specification of a solubility constraint would likely only reduce soil standards for some organic substances for the default conditions [e.g., for ethylbenzene, the existing back-calculated leachate concentration exceeds the substance pure-phase solubility (i.e., a constraint is not currently applied),	Evaluate adoption of a modified solubility constraint (50% of pure-phase solubility for organic substances) at the time of updated standards calculation. [Potential decreased soil standards for some substances (ethylbenzene and PCP)].	Not applicable.

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						while for PCP, the back-calculated leachate concentrations for the DW and LW pathways at low pH (pH < 5) are constrained to the substance pure-phase solubility]. However, the constraint would likely apply to more substances under Protocol 2 calculations.		
31	Documentation	CSST model derivation documents developed (listed at the end of this document). Help files also provided within the model.	Published by CCME.	Provided as Protocol 13.	21. Make the documentation changes to the groundwater protocol suggested by Mr. Chris Neville of S.S. Papadopulos & Associates, Inc. of Waterloo, Ontario.	Agreed. Revised model to be fully documented so that software is easy to use and reflects the spirit of the level of documentation changes proposed by Neville as presented in SABCS, 2005.	Revise and update model documentation.	Revise and update to incorporate the changes identified in this document.
32	Background adjustment	Included. Background soil concentration is added to calculated concentration for most substances.	Included. Background concentration or calculated standard is used, whichever is greater.	Not applicable as Protocol 13 is only utilized where soil concentrations exceed background values.	Modify background adjustment.	Regional background soil concentrations are available under Technical Guidance 4 for inorganic substances. The background adjustment in the CSST model consists of addition of the regional background concentration to the calculated soil standard for most substances. This may not be conservative where the calculated standard exceeds the background concentration. A more conservative representation of the background adjustment is to report either the background concentration or the calculated standard, whichever is greater.	Revise the background adjustment to report either the background concentration or the calculated standard, whichever is greater. [Decrease in soil standards for some substances].	None.
33	Hazardous waste (leachate quality standards)	Included but not active in model calculations.	Not included.	Not applicable as hazardous waste must be evaluated outside of Protocol 13.	Separate hazardous waste leachate quality standards from the CSST model.	The hazardous waste leachate quality standards are included in the CSST model but calculations are not reported in the interface. The hazardous waste option was	Remove the hazardous waste leachate quality standards from the CSST model as hazardous waste soil quality is assessed separately under	None.

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						developed in the initial CSST model formulation when hazardous waste leachate quality standards were used as water use standards in place of, or in addition to, the Schedule 6 water use standards. However, current day assessment of water quality under the CSR is based on the Schedule 6 water use standards. Hazardous waste soil quality is also assessed separately under the CSR. In addition, measures are underway within the ministry for separation of the Hazardous Waste and Contaminated Sites Regulations. Based on the above, it is proposed that hazardous waste leachate quality standards are best assessed outside of the CSST model.	the Contaminated Sites Regulation. If desired, calculation of soil standards based on leachate quality standards may still be done by manual entry in the model interface. [No change to soil standards].	
34	AW pathway water use standards	Aquatic life water use standards are included.	Current water use guidelines are used.	Current water use standards are used.	Incorporate soil standards calculation for both freshwater and estuarine/marine AW standards.	The aquatic life water use standards in the model are based on the CSR 1997 Schedule 6 standards. A distinction between fresh and estuarine/marine AW water use standards was introduced in the CSR in 2002. The updated water use standards are currently input manually into the model. The model should be updated to incorporate the distinction in AW types along with updating of the applicable water use standards.	Update the model to include both freshwater and estuarine/marine AW water use standards. [No change to soil standards].	None – most current AW standards must always be used in Protocol 13.
35	Exclusion/preclusion factors	Default values used in model. Site-specific values with limits prescribed in Protocol 2.	Default values used in model. Management or other limits presented for Tier II/III assessment.	Some default values provided. Preclusions and limits are also prescribed in Protocol 13.	Incorporate site-specific “exclusion” factors into model which would preclude calculation of numerical standards and force site-specific risk	Conceptual agreement. Modification of default values is only permitted in Protocol 2. Limits on certain input parameters (distance to receptor, linear velocity, infiltration rates, porosities, fraction	None at present. Future consideration – evaluate existing and potential new constraints/limits to	None at present.

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					assessment (e.g., K > 450 m/yr, distance to receptor < 10 m, volume of contaminated soil > 300 m3, presence of LNAPL, etc.).	of organic carbon) and restrictions (no LNAPL) are already prescribed in Protocol 2. The issue is best addressed as a future consideration.	ensure conservativeness of model.	
36	Dilution downgradient of source zone	Not included.	Not included.	Not included.	Incorporate allowance for dilution due to infiltration downgradient of source zone along saturated zone transport pathway.	Conceptual agreement. Incorporation of downgradient dilution due to infiltration would require an alternate transport solution and model coding. An alternate model formulation would also no longer be harmonized with CCME. Such an exercise would require a longer time period than available for the omnibus standards updating project. The issue is best addressed as a future consideration.	None at present. Future consideration – evaluate the consistency in, and feasibility of, incorporation of this attenuation mechanism.	None at present.

* Note - Anticipated changes to matrix numerical soil standards noted in square parentheses [ ].

Acronyms

ASLP	Australian Standard Leaching Procedure (Australian Standard 4439.2 and 4439.3)
CCME	Canadian Council of Ministers of the Environment
CSST	Contaminated Sites Soil Task Group
DAF	Default Attenuation Factor – as per US EPA SSG, the DAF represents the degree of attenuation arising from the processes of unsaturated zone transport, groundwater mixing and saturated zone transport
DF	Dilution Factor – as used by BC Environment, the DF represents the degree of attenuation arising from groundwater mixing
EPA SSL	Soil Screening Level as determined using US EPA SSG
MEP	Multiple Extraction Procedure (Method 1320 in USEPA SW846)
SABCS	Science Advisory Board for Contaminated Sites in British Columbia
SLRA	Screening Level Risk Assessment
SPLP	Synthetic Precipitation Leaching Procedure (Method 1312 in USEPA SW846)
SSS	Site-Specific Numerical Soil Standards
TCLP	Toxicity Characteristic Leaching Procedure (Method 1311 in USEPA SW846)