APPENDIX K

Biological Uptake Factors

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1.0 EXPOSURE ASSESSMENT

To evaluate the level of exposure for each ecological receptor to each contaminant of potential concern (COPC) assessed in the ecological risk assessment (ERA), it is necessary to first estimate the concentration of each COPC in various media or biological tissues (*e.g.,* soil, water, sediment, and representative plant and animal tissues). A baseline sampling program was carried out to characterize the pre-existing COPC concentrations in soil, water, sediment, and a variety of biological tissues relevant to the ERA (including freshwater fish, soil invertebrates, terrestrial plants, and small mammals). The results of the baseline sampling program can be found in Jacques Whitford (2009).

To estimate the potential environmental effects of the Project for each receptor location, modelled air concentrations and COPC deposition rates are used to estimate exposure point concentration (EPC) values for all COPC evaluated in this ERA. EPC values for soil, water, sediment, terrestrial plants, small mammals (*i.e.,* prey), and freshwater fish were calculated using environmental fate and transport equations provided in U.S. EPA (2005a, Appendix A), and are additive to the baseline concentrations. EPC values for the remaining biota (soil invertebrates, benthic invertebrates, aquatic plants) were calculated directly in the ERA model, using COPC-specific uptake factors which describe the relationships between chemical concentrations in environmental media and concentrations in biota. In the following sections, details of the equations and methods used to derive EPC values for biota in the ERA are discussed.

The term “uptake factor” (UP) will be used generically in this document to refer to any of several specific terms, including:

- Bioaccumulation Factor (BAF), the ratio of a COPC concentration in an organism or biological tissue (*e.g.,* a soil invertebrate) to the concentration in a surrounding medium (*e.g.,* soil);
- Bioconcentration Factor (BCF), a specific term that refers to the ratio of a COPC concentration in an aquatic organism (*e.g.,* fish) to the concentration in the surrounding water; and
- Biota Sediment Accumulation Factor (BSAF), a term specifically applied to organic contaminants, that refers to the ratio of the lipid normalized COPC concentration in an aquatic organism, to the organic carbon normalized COPC concentration in sediment.

Common sources of error in environmental fate and transport calculations involve confusion between wet and dry weight units for chemical concentrations in soil, sediment, and biota, and unit errors stemming from the fact that inorganic substances are commonly reported in units of milligrams (mg/L or mg/kg) in environmental media, whereas many organic substances are reported in units of µg (micrograms), ng (nanograms), or even pg (picograms). To manage these problems in this ERA, all chemical concentrations are converted to units of mg/L or mg/kg. For water, all chemical concentrations and intakes are based on units of mg/L. For soil and sediment, all concentrations are expressed on a dry weight basis (mg/kg dry weight soil or sediment). For plant and animal tissues, all concentrations are expressed on a wet weight basis (mg/kg wet weight tissue).

The uptake factor literature is likewise inconsistent, with some uptake factors being expressed on a wet tissue basis, others on a dry tissue basis, and still others (*e.g.*, BSAF) being normalized on the basis of tissue lipid to sediment organic carbon content. The ERA model requires EPC values on a wet tissue basis for biota that are ingested as foods by ecological receptors. Therefore, where possible, uptake factors are expressed on a wet tissue basis; where necessary, correction factors are applied in order to convert from dry weight tissue units to a wet tissue basis.

1.1 BIOLOGICAL UPTAKE FACTORS

The generalized uptake factor equation used to calculate a COPC concentration in an organism or biological tissue (*e.g.,* soil invertebrates) from the concentration in a surrounding medium (*e.g.,* soil) is as follows:

$$EPC_j = EPC_i \times UP_{ij} \qquad \text{Equation 1}$$

where:

- EPC_j = exposure point concentration in biological compartment *j* (*e.g.,* mg/kg wet weight soil invertebrate tissue);
- EPC_i = exposure point concentration in environmental medium i (*e.g.,* mg/kg dry soil); and
- UP_{ij} = uptake factor from surrounding medium (in this case soil) to the target biological tissue (*e.g.,* mg/kg wet tissue / mg/kg dry soil).

1.1.1 Soil to Terrestrial Invertebrates UP_{SI}

Uptake factors for soil-to-terrestrial invertebrates (UP_{SI}) are generally reported for earthworms due to the availability of information in the literature, and a relative paucity of information with regards to insects. The ERA, therefore, focuses on earthworms as the "model" soil invertebrate, due to the relative abundance of data and models to predict contaminant uptake, as well as the perceived importance of earthworms in food webs.

The UP_{SI} are estimated in dry weight units (*i.e.,* mg/kg dry soil invertebrate / mg/kg dry soil) and are converted to wet weight where necessary assuming that the fresh earthworm contains 84% water and 16% dry solids (typical value for earthworms; U.S. EPA 1993). A summary of the equations, point estimates, and relevant correction factors for soil to terrestrial invertebrate uptake is provided in Table 1.

1.1.1.1 Organics

Dioxins, Furans, and PCBs

Soil-to-earthworm bioaccumulation models for PCBs and 2,3,7,8-TCDD (equivalent) are derived from Development and Validation of Bioaccumulation Models for Earthworms (Sample *et al.* 1998, Table 12). The standard equation developed by Sample *et al.* (1998) has the form:

$$\ln(C_{worm}) = B_o + B_1 \times (\ln (C_{soil})) \qquad \text{Equation 2}$$

where, C_{worm} is the COPC concentration in an earthworm (mg/kg dry weight), C_{soil} is the COPC concentration in soil (mg/kg dry weight), and B_0 and B_1 are regression constants subject to statistical fitting procedures. The data range from Sample *et al.* (1998) was from 0.00001 mg/kg to 0.093 mg/kg, so the UP is bounded by values defined by this data range. The equation explicitly applies to earthworms that were depurated prior to chemical analysis to eliminate soil content in the gut. The equation in the ERA model is modified slightly in order that it can be used to estimate a soil to invertebrate concentration ratio that is appropriate for the expected soil contaminant concentration. It is assumed that the uptake factor model for 2,3,7,8-TCDD can also be applied to other dioxin and furan congeners. This assumption is reasonable because 2,3,7,8-TCDD is among the more readily accumulated and persistent congeners. Thus, the equation in the ERA model for the accumulation of dioxins and furans by soil invertebrates becomes:

$$UP_{SI} = e^{(Bo + B1 * \ln(Csoil))} / C_{soil} \qquad \text{Equation 3}$$

For dioxins and furans (as 2,3,7,8-TCDD) the equation based on Sample *et al.* (1998) is:

$$UP_{SI} = e^{(3.533 + 1.182*\ln(Csoil))} / C_{soil} \qquad \text{Equation 4}$$

For PCBs, the equation based on Sample *et al.* (1998) is:

$$UP_{SI} = e^{(1.410 + 1.361*\ln(Csoil))} / C_{soil} \qquad \text{Equation 5}$$

Pentachlorophenol

The soil-to-earthworm bioaccumulation factor for pentachlorophenol is derived from the U.S. EPA Eco-SSL document for pentachlorophenol, which stipulates a median BAF in soil invertabrates of 14.63 based on regression analysis.

Other Organics

The soil-to-earthworm bioaccumulation model for the remaining organic compounds is derived from U.S. EPA (2005a) as based upon Jager (1998), presented here to give the uptake factor on the dry weight basis for the earthworm (mg/kg dw tissue / mg/kg dw soil) and is calculated as:

$$UP_{SI} = ((f_{water} + (f_{lipid} \times K_{ow})) / (F_{oc} \times K_{oc})) / 0.16 \qquad \text{Equation 6}$$

where f_{water} is the water content of the worm (0.84; U.S. EPA, 1993), f_{lipid} is the lipid content of the worm (0.01), f_{OC} is the fraction of organic carbon in soil (assumed to be 0.01), and K_{OC} is the water to organic carbon partitioning coefficient (L/kg OC). The value 0.16 is the dry solids content of the

worm. K_{OW} values were obtained from various sources and K_{OC} values were calculated as: K_{ow} x 0.41 (Karickhoff 1981). K_{OW} values used in the uptake equations were the same as those listed in Appendix D.

Bioavailability and metabolic factors (unitless) for use with this equation as multipliers before calculating the final concentration in earthworms were estimated based on K_{OW}. Estimated values for bioavailability range from 0.1 to 1 while values for metabolic factor range from 0.05 to 1 (Table 1).

1.1.1.2 Inorganics

Soil-to-earthworm bioaccumulation models for inorganic elements were derived (on a dry weight basis) from Sample *et al.* (1998; Table 12), for the following COPC:

Arsenic	$UP_{SI}=(e^{(-1.421 + 0.706*\ln(Csoil))}) / C_{soil}$	Equation 7
Cadmium	$UP_{SI}=(e^{(2.114 + 0.795*\ln(Csoil))}) / C_{soil}$	Equation 8
Lead	$UP_{SI}=(e^{(-0.218 + 0.807*\ln(Csoil))}) / C_{soil}$	Equation 9
Zinc	$UP_{SI}=(e^{(4.449 + 0.328*\ln(Csoil))}) / C_{soil}$	Equation 10

Point estimates of UP_{SI} were also obtained from Sample *et al.* (1998) for barium, beryllium, cobalt, silver, and vanadium (Table 1). For chromium, nickel, inorganic mercury, and selenium the regression equations presented by Sample *et al.* (1998) were not considered to be of sufficient reliability to use. Therefore, for those elements, the median values of data presented by Sample *et al.* (1998, Table 11) were selected as follows:

- chromium – the median value (0.306) was selected, as the distribution was approximately lognormal;
- nickel – the median value (1.06) was selected, as the distribution was approximately normal; and
- inorganic mercury – the median value (1.693) was selected, as the distribution was approximately lognormal; and
- selenium – the median value (0.985) was selected, as the distribution was approximately lognormal;

The methyl mercury UP_{SI} value is 53.13, obtained from U.S. EPA (1999 Appendix C Table C1; converted to dry weight basis). For antimony, boron, and thallium an UP_{SI} of 1 was used based on U.S. EPA (2007). The UP_{SI} for tin is based off that of lead, given their proximity in the periodic table and thus their assumed similar inherent chemical properties.

Table 1: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Soil to Terrestrial Invertebrates

COPC	UP_{SI} Uptake Factor: Soil to Invertebrate (mg/kg-dry tissue / mg/kg-dry soil)	Uptake Factor Reference	Soil to Invertebrate Bioavailability Factor (Unitless)	Soil to Invertebrate Bioavailability Factor Reference	Soil to Invertebrate Metabolic Factor (Unitless)	Soil to Invertebrate Metabolic Factor Reference
Polycyclic Aromatic Hydrocarbons						
Acenaphthene	1.54E+01	Jager (1998)	2.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.
Acenaphthylene	1.54E+01	Jager (1998)	2.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.
Anthracene	1.53E+01	Jager (1998)	2.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.
Fluoranthene	1.53E+01	Jager (1998)	2.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.
Fluorene	1.53E+01	Jager (1998)	2.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.
Phenanthrene	1.53E+01	Jager (1998)	2.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.
Benz(a)anthracene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.

Table 1: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Soil to Terrestrial Invertebrates

COPC	UP_{SI} Uptake Factor: Soil to Invertebrate (mg/kg-dry tissue / mg/kg-dry soil)	Uptake Factor Reference	Soil to Invertebrate Bioavailability Factor (Unitless)	Soil to Invertebrate Bioavailability Factor Reference	Soil to Invertebrate Metabolic Factor (Unitless)	Soil to Invertebrate Metabolic Factor Reference
Benzo(a)pyrene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	5.00E-01	Potential to be metabolized decreases with increasing molecular size.
Benzo(e)pyrene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	5.00E-01	Potential to be metabolized decreases with increasing molecular size.
Benzo(e)fluorene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	5.00E-01	Potential to be metabolized decreases with increasing molecular size.
Benzo(b)fluorene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	5.00E-01	Potential to be metabolized decreases with increasing molecular size.
Benzo(b)fluoranthene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.
Benzo(g,h,i)perylene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	5.00E-01	Potential to be metabolized decreases with increasing molecular size.
Benzo(k)fluoranthene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.

Table 1: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Soil to Terrestrial Invertebrates

COPC	UP_{SI} Uptake Factor: Soil to Invertebrate (mg/kg-dry tissue / mg/kg-dry soil)	Uptake Factor Reference	Soil to Invertebrate Bioavailability Factor (Unitless)	Soil to Invertebrate Bioavailability Factor Reference	Soil to Invertebrate Metabolic Factor (Unitless)	Soil to Invertebrate Metabolic Factor Reference
Chrysene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.
Dibenz(a,c)anthracene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	5.00E-01	Potential to be metabolized decreases with increasing molecular size.
Dibenz(a,h)anthracene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	5.00E-01	Potential to be metabolized decreases with increasing molecular size.
Indeno(1,2,3-cd)pyrene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	5.00E-01	Potential to be metabolized decreases with increasing molecular size.
Perylene	1.52E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	5.00E-01	Potential to be metabolized decreases with increasing molecular size.
Pyrene	1.53E+01	Jager (1998)	1.00E-01	Bioavailability decreases with increasing molecular size.	1.00E-01	Potential to be metabolized decreases with increasing molecular size.
Dioxins and Furans						
2,3,7,8-TCDD Equivalent	3.07E+00	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Total PCBs						
Aroclor 1254 (Total PCBs)	7.77E-01	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chlorinated Monocyclic Aromatics						

Table 1: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Soil to Terrestrial Invertebrates

COPC	UP_{SI} Uptake Factor: Soil to Invertebrate (mg/kg-dry tissue / mg/kg-dry soil)	Uptake Factor Reference	Soil to Invertebrate Bioavailability Factor (Unitless)	Soil to Invertebrate Bioavailability Factor Reference	Soil to Invertebrate Metabolic Factor (Unitless)	Soil to Invertebrate Metabolic Factor Reference
Dichlorobenzene	1.56E+01	Jager (1998)	5.00E-01	Bioavailability assumed to be moderate when log Kow is between 3 and 5	1.00E-01	Potential for metabolism assumed to be moderate when log Kow is between 3 and 5
1,2,4-Trichlorobenzene	1.54E+01	Jager (1998)	5.00E-01	Bioavailability assumed to be moderate when log Kow is between 3 and 5	1.00E-01	Potential for metabolism assumed to be moderate when log Kow is between 3 and 5
1,2,4,5-Tetrachlorobenzene	1.53E+01	Jager (1998)	5.00E-01	Bioavailability assumed to be moderate when log Kow is between 3 and 5	1.00E-01	Potential for metabolism assumed to be moderate when log Kow is between 3 and 5
Pentachlorobenzene	1.53E+01	Jager (1998)	1.00E-01	Bioavailability assumed to be low when log Kow is >5	1.00E+00	Potential for metabolism assumed to be low when log Kow is >5
Hexachlorobenzene	1.53E+01	Jager (1998)	1.00E-01	Bioavailability assumed to be low when log Kow is >5	1.00E+00	Potential for metabolism assumed to be low when log Kow is >5
Pentachlorophenol	1.46E+01	US EPA (2005a)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chlorinated Solvents and Derivatives						
Carbon Tetrachloride	1.73E+01	Jager (1998)	1.00E+00	Bioavailability assumed to be high when log Kow is <3	5.00E-02	Potential for metabolism assumed to be high when log Kow is <3
Chloroform	2.80E+01	Jager (1998)	1.00E+00	Bioavailability assumed to be high when log Kow is <3	5.00E-02	Potential for metabolism assumed to be high when log Kow is <3

Table 1: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Soil to Terrestrial Invertebrates

COPC	UP_{SI} Uptake Factor: Soil to Invertebrate (mg/kg-dry tissue / mg/kg-dry soil)	Uptake Factor Reference	Soil to Invertebrate Bioavailability Factor (Unitless)	Soil to Invertebrate Bioavailability Factor Reference	Soil to Invertebrate Metabolic Factor (Unitless)	Soil to Invertebrate Metabolic Factor Reference
Dichloromethane	7.94E+01	Jager (1998)	1.00E+00	Bioavailability assumed to be high when log Kow is <3	5.00E-02	Potential for metabolism assumed to be high when log Kow is <3
Trichlorofluoromethane (FREON 11)	1.93E+01	Jager (1998)	1.00E+00	Bioavailability assumed to be high when log Kow is <3	5.00E-02	Potential for metabolism assumed to be high when log Kow is <3
Chlorinated Alkanes/Alkenes						
1,1,1-Trichloroethane	1.93E+01	Jager (1998)	1.00E+00	Bioavailability assumed to be high when log Kow is <3	5.00E-02	Potential for metabolism assumed to be high when log Kow is <3
Other Organics						
Bromoform	2.06E+01	Jager (1998)	1.00E+00	Bioavailability assumed to be high when log Kow is <3	5.00E-02	Potential for metabolism assumed to be high when log Kow is <3
o-Terphenyl	1.53E+01	Jager (1998)	1.00E-01	Bioavailability assumed to be low when log Kow is >5	1.00E+00	Potential for metabolism assumed to be low when log Kow is >5
Inorganics						
Antimony	1.00E+00	Conservative Default - US EPA (2007)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Arsenic	1.31E-01	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Barium	9.10E-02	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Beryllium	4.50E-02	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Boron	1.00E+00	Conservative Default	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Cadmium	9.55E+00	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default

Table 1: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Soil to Terrestrial Invertebrates

COPC	UP_{SI} Uptake Factor: Soil to Invertebrate (mg/kg-dry tissue / mg/kg-dry soil)	Uptake Factor Reference	Soil to Invertebrate Bioavailability Factor (Unitless)	Soil to Invertebrate Bioavailability Factor Reference	Soil to Invertebrate Metabolic Factor (Unitless)	Soil to Invertebrate Metabolic Factor Reference
Chromium (Total)	3.06E-01	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chromium VI	3.06E-01	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Cobalt	1.22E-01	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Lead	4.66E-01	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Mercury - Inorganic	1.69E+00	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Methyl Mercury	5.31E+01	US EPA (1999a)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Nickel	1.06E+00	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Selenium	9.85E-01	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Silver	2.05E+00	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Thallium	1.00E+00	Conservative Default	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Tin	5.16E-01	Based on Lead	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Vanadium	4.20E-02	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Zinc	4.54E+00	Sample *et al.* (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default

1.1.2 Sediment to Aquatic Plants, $UP_{SAP(fw)}$

1.1.2.1 Organics

Uptake of organic COPC by freshwater aquatic plants was assumed to occur wholly as a result of association with sediment. This assumption was deemed reasonable and conservative given the tendency of most organic compounds to preferentially partition into sediments, which can be easily inferred given their high log K_{OC} values (higher values representing a greater tendency to adsorb to particulate matter).

For most organic COPC, freshwater aquatic plant concentrations were derived using the equation of Vanier *et al.* (1999; 2001; based on PCBs), but only for those COPC with a log K_{OW} greater than or equal to 3.9 (PAHs, PCBs, 2,3,7,8-TCDD equivalent, 1,2,4-trichlorobenzene, 1,2,4,5-tetrachlorobenzene, penta- and hexachlorobenzene, pentachlorophenol, and o-terphenyl):

$$UP_{SAP(fw)} = (10^{1.611 + 0.964 \times \log(Csed)} / Csed) \times 0.00037 \qquad \text{Equation 11}$$

Where 0.00037 is the mean lipid concentration of aquatic plants (mg/kg ww) (n = 28 from roots and shoots, based on Vanier *et al.* 1999).

Since PCBs are persistent organic compounds, the congeners exhibited a wide range of log K_{OW} (and K_{OC}) values, and the model represents a fundamental balance between the tendency of organic compounds to partition into plant tissues, it is reasonable to assume that the relationship will be reasonable and conservative when applied to other organic compounds having similar log K_{OW} values.

For organic COPC with a log K_{OW} less than 3.9 $UP_{SAP(fw)}$ was estimated based on terrestrial plant COPC uptake (UP_{SP}), as follows:

$$UP_{SAP(fw)} = SP_{bio} \times P_{mf} \times 0.13 \times UP_{SP} \qquad \text{Equation 12}$$

Where: SP_{bio} represents the soil to plant bioavailability factor (unitless), P_{mf} represents the plant metabolic factor (unitless), 0.13 represents an aquatic plant dry-weight to wet-weight conversion factor, accounting for 87% plant moisture, and UP_{SP} comes from Ryan *et al.* (1988) as follows:

$$UP_{SP} = (0.784*(10^{(-0.434*((\log Kow - 1.78)\text{^}2) / 2.44)}) \times (10^{(0.95*(\log Kow - 2.05))} + 0.82)) \times S_{BD}/(S_{MC} + S_{BD}*(10^{(\log Koc)} * F_{oc}) /0.15 \qquad \text{Equation 13}$$

Where: S_{BD} represents soil bulk density (1.487 g/cm^3) and S_{MC} represents soil moisture content (0.25 cm^3/cm^3). The terrestrial plant dry-weight to wet-weight conversion factor is set as 0.15. Note that in place of soil concentration (Csoil), the estimation of sediment to aquatic plant uptake used the sediment concentration (Csed).

1.1.2.2 Inorganics

For all inorganic COPC (unless a point estimate was provided), $UP_{SAP(fw)}$ was estimated based on terrestrial plant COPC uptake (UP_{SP}), as described in Equation 12. Trace element uptake factors from soil to plant tissue are based on a combination of constant uptake factors, or where available, regression-based uptake factors that take into consideration the underlying concentration in

sediment. UP_{SP} for boron, methyl mercury, silver, thallium, and tin were based on the 95% UCL of the geometric mean of UP_{SP} values from a variety of sources including Sheppard and Evenden (1988, 1990), Sheppard and Sheppard (1991), Torres and Johnson (2001) and U.S. EPA (2005b). All other UP_{SP} were used as recommended by the U.S. EPA (2005b) based on Bechtel Jacobs (1998).

Table 2: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Sediment to Aquatic Plants

COPC	$UP_{SAP(FW)}$ Uptake Factor: Sediment to Aquatic Plant (mg/kg-wet tissue / mg/kg-dry sed)	Uptake Factor Reference	Soil to Plant Bioavailability Factor (Unitless)	Soil to Plant Bioavailability Factor Reference	Soil to Plant Metabolic Factor (Unitless)	Soil to Plant Metabolic Factor Reference
Polycyclic Aromatic Hydrocarbons						
Acenaphthene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Acenaphthylene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Anthracene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Fluoranthene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Fluorene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Phenanthrene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Benz(a)anthracene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Benzo(a)pyrene	1.74E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Benzo(e)pyrene	2.26E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Benzo(e)fluorene	2.55E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Benzo(b)fluorene	2.57E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Benzo(b)fluoranthene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Benzo(g,h,i)perylene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Benzo(k)fluoranthene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chrysene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Dibenz(a,c)anthracene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Dibenz(a,h)anthracene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default

Table 2: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Sediment to Aquatic Plants

COPC	$UP_{SAP(FW)}$ Uptake Factor: Sediment to Aquatic Plant (mg/kg-wet tissue / mg/kg-dry sed)	Uptake Factor Reference	Soil to Plant Bioavailability Factor (Unitless)	Soil to Plant Bioavailability Factor Reference	Soil to Plant Metabolic Factor (Unitless)	Soil to Plant Metabolic Factor Reference
Indeno(1,2,3-cd)pyrene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Perylene	1.74E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Pyrene	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Dioxins and Furans						
2,3,7,8-TCDD Equivalent	2.49E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Total PCBs						
Aroclor 1254 (Total PCBs)	1.68E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chlorinated Monocyclic Aromatics						
Dichlorobenzene	3.02E-01	From Upsp (Ryan *et al.*, 1988)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
1,2,4-Trichlorobenzene	1.64E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
1,2,4,5-Tetrachlorobenzene	1.78E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Pentachlorobenzene	1.77E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Hexachlorobenzene	1.77E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Pentachlorophenol	1.84E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chlorinated Solvents and Derivatives						
Carbon Tetrachloride	7.88E-01	From Upsp (Ryan *et al.*, 1988)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chloroform	1.76E+00	From Upsp (Ryan *et al.*, 1988)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Dichloromethane	2.41E+00	From Upsp (Ryan *et al.*, 1988)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Trichlorofluoromethane (FREON 11)	1.10E+00	From Upsp (Ryan *et al.*, 1988)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chlorinated Alkanes/Alkenes						

Table 2: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Sediment to Aquatic Plants

COPC	$UP_{SAP(FW)}$ Uptake Factor: Sediment to Aquatic Plant (mg/kg-wet tissue / mg/kg-dry sed)	Uptake Factor Reference	Soil to Plant Bioavailability Factor (Unitless)	Soil to Plant Bioavailability Factor Reference	Soil to Plant Metabolic Factor (Unitless)	Soil to Plant Metabolic Factor Reference
1,1,1-Trichloroethane	1.10E+00	From Upsp (Ryan *et al.,* 1988)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Other Organics						
Bromoform	1.25E+00	From Upsp (Ryan *et al.,* 1988)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
o-Terphenyl	2.41E-02	Vanier *et al.* (2001)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Inorganics						
Antimony	5.13E-03	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Arsenic	4.88E-03	US EPA 2007, Eco-SSL guidance	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Barium	2.03E-02	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Beryllium	9.14E-02	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Boron	1.81E-02	From UPsp (Geometric mean from various sources)	4.70E-02 [a]	Gupta, 1979; Gupta and McLeod 1981	1.00E+00	Conservative Default
Cadmium	1.10E-01	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chromium (Total)	5.33E-03	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Chromium VI	5.33E-03	From UPsp (US EPA 2007, Eco-SSL guidance) Assumed to be the same as Total Cr.	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Cobalt	9.75E-04	From UPsp (From UPsp (US EPA 2007, Eco-SSL guidance))	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Lead	1.56E-02	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Mercury - Inorganic	1.74E-01	Bechtel Jacobs (1998)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Methyl Mercury	1.78E-02	US EPA (1999), App C, Table C2	1.00E+00	Conservative Default	1.00E+00	Conservative Default

Table 2: Summary of the Equations, Point Estimates, and Relevant Correction Factors for Sediment to Aquatic Plants

COPC	$UP_{SAP(FW)}$ Uptake Factor: Sediment to Aquatic Plant (mg/kg-wet tissue / mg/kg-dry sed)	Uptake Factor Reference	Soil to Plant Bioavailability Factor (Unitless)	Soil to Plant Bioavailability Factor Reference	Soil to Plant Metabolic Factor (Unitless)	Soil to Plant Metabolic Factor Reference
Nickel	8.13E-03	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Selenium	6.60E-02	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Silver	4.50E-03	From UPsp (Geometric mean from various sources)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Thallium	3.21E-04	From UPsp (Geometric mean from various sources)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Tin	2.70E-03	From UPsp (Geometric mean from various sources)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Vanadium	6.31E-04	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default
Zinc	9.94E-02	From UPsp (US EPA 2007, Eco-SSL guidance)	1.00E+00	Conservative Default	1.00E+00	Conservative Default

a. Available boron was assumed to be 4.7% of total boron; less than 5% of total soil B is found in plant available forms (Gupta, 1979 in MOE, 1996; Gupta and McLeod, 1981).

1.1.3 Sediment to Benthic Invertebrates, UP_{SBI}

1.1.3.1 Organics

Bioconcentration factors from freshwater sediment to benthic aquatic invertebrates (UP_{SBI}) for organic compounds were obtained from a BSAF equation derived by DiToro and McGrath (2000) shown below.

$$BSAF = C_L/C_{S,OC} \quad \text{or,}$$

$$\log(BSAF) = \log C_L - \log C_{S,OC} \qquad \text{Equation 14}$$

where: C_L = the concentration of a substance in the lipid of a benthic organism (mmol/kg lipid); and

$C_{S,OC}$ = the concentration of the same substance in the OC fraction of the sediment (mmol/kg organic carbon).

Using additional equations presented by DiToro and McGrath (2000), equation 14 can be simplified to:

$$BSAF = 10^{\wedge(-0.038\log(Kow)-0.00028)} \qquad \text{Equation 15}$$

This equation yields theoretical BSAF values that range from 0.916 for a log K_{OW} value of 1.0, to 0.592 for a log K_{OW} value of 6. Assuming lipid and organic carbons fractions are similar, the above equation (15) requires an adjustment to convert the tissue concentration to a dry weight basis. Gewurtz *et al.* (2000) reported a percent moisture content of invertebrates of 76% (69% to 84%). A metabolic factor ranging from 0.01 to 1 is also applied to equation 14 to account for metabolism of organic COPC. These metabolic factors were determined based on comparison to previously collected empirical data (JDAC, 2002), or were modified based on log K_{OW} values to reflect the apparent ease with which the COPC may be metabolized. The final UP_{SBI} equation used in the ERA model is presented below.

$$UP_{SBI} = (\text{COPC Metabolic Factor}) \times 0.24 \times 10^{\wedge(-0.038\log(Kow)-0.00028)} \qquad \text{Equation 16}$$

Table 3: Summary of Sediment to Benthic Invertebrate Uptake Factors for Organic COPC

COPC	$UP_{SBI(fw)}$ (mg/kg-wet tissue / mg/kg-dry sed)	COPC Specific Metabolic Factors
Polycyclic Aromatic Hydrocarbons		
Low Molecular Weight PAHs		
Acenaphthene	4.11E-03	1.00E-01
Acenaphthylene	4.07E-03	1.00E-01
Anthracene	3.90E-03	1.00E-01
Fluoranthene	3.73E-03	1.00E-01
Fluorene	4.00E-03	1.00E-01
Phenanthrene	3.90E-03	1.00E-01
High Molecular Weight PAHs		
Benz(a)anthracene	3.51E-03	1.00E-01
Benzo(a)pyrene	1.71E-02	5.00E-01
Benzo(e)pyrene	1.64E-02	5.00E-01
Benzo(a)fluorene	3.60E-03	1.00E-01
Benzo(b)fluorene	3.49E-03	1.00E-01
Benzo(b)fluoranthene	3.38E-03	1.00E-01
Benzo(g,h,i)perylene	1.64E-02	5.00E-01
Benzo(k)fluoranthene	3.39E-03	1.00E-01
Chrysene	3.51E-03	1.00E-01
Dibenz(a,c)anthracene	1.61E-02	5.00E-01
Dibenz(a,h)anthracene	1.64E-02	5.00E-01
Indeno(1,2,3-cd)pyrene	1.62E-02	5.00E-01
Perylene	1.67E-02	5.00E-01
Pyrene	3.76E-03	1.00E-01
Dioxins and Furans		
2,3,7,8-TCDD Equivalent	3.08E-02	1.00E+00
PCBs		
Aroclor 1254 (Total PCBs)	3.27E-02	1.00E+00
Chlorinated Monocyclic Aromatics		
Dichlorobenzene	4.25E-02	1.00E+00
1,2,4-Trichlorobenzene	4.07E-02	1.00E+00
1,2,4,5-Tetrachlorobenzene	3.79E-02	1.00E+00
Pentachlorobenzene	3.67E-02	1.00E+00
Hexachlorobenzene	3.63E-02	1.00E+00
Pentachlorophenol	3.70E-02	1.00E+00
Chlorinated Solvents and Derivatives		
Carbon Tetrachloride	4.52E-02	1.00E+00
Chloroform	4.85E-02	1.00E+00
Dichloromethane	5.15E-02	1.00E+00
Trichlorofluoromethane (FREON 11)	4.64E-02	1.00E+00
Chlorinated Alkanes/Alkenes		
1,1,1-Trichloroethane	4.64E-02	1.00E+00
Other Organics		
Bromoform	4.69E-02	1.00E+00
o-Terphenyl	3.64E-02	1.00E+00

1.1.3.2 Inorganics

Biota-sediment accumulation factors for inorganic COPC used in the ERA were derived from published literature sources. Preference was given to studies reporting actual measured BSAFs. For COPC with no published BSAF, a value was derived using studies reporting concentrations in both sediment and aquatic invertebrates. Where multiple values were available for a COPC, preference was given to those most representative of aquatic invertebrate communities from the LRASA, and those considered potential avian and mammalian prey. Invertebrate concentrations were frequently reported in the literature by authors on a dry weight basis. In order to determine a wet weight BSAF, the value was modified by multiplying by a dry fraction of 0.24 (invertebrate moisture content of 76% derived from Gewurtz *et al.* 2000).

In all but a few cases, organism-specific BSAFs were first calculated using the data provided in published studies. Values were not normalized for lipid or organic carbon content. Given the number of variables that may influence the BSAF (*e.g.,* water pH, sediment texture), values were derived using a scope of data that reflected a range of environmental conditions, including pristine environments, lakes of varying pH, and areas impacted by mining and industrial activities. The BSAFs used in the risk assessment model were calculated as the arithmetic mean of literature acquired values when the range did not exceed one order of magnitude and as the geometric mean if the BSAF values acquired varied by more than one order of magnitude. BSAF values used in the ERA are presented in Table 5, and a short description of the BSAF for each inorganic is provided below.

Table 4: Summary of Sediment to Benthic Invertebrate Uptake Factors for Inorganic COPC

COPC	$UP_{SBI(fw)}$ mg/kg-wet tissue/ mg/kg-dry sed	Reference
Antimony	1.13E-02	Haus *et al.,* 2007
Arsenic	1.03E-01	ORNL, 1998
Barium	1.37E-01	Hamilton *et al.,* 2002 and Garn *et al.,* 2001
Beryllium	1.32E-01	Hamilton *et al.,* 2002 and Garn *et al.,* 2001
Boron	2.29E-01	Hamilton *et al.,* 2002 and Garn *et al.,* 2001
Cadmium	3.25E-01	ORNL, 1998
Chromium (Total)	7.27E02	ORNL, 1998
Chromium VI	NA	Does not bioconcentrate (reduced to Cr(III) in tissue)
Cobalt	2.4E-03	Garn *et al.,* 2001

Lead	2.74E-02	ORNL, 1998
Mercury - Inorganic	1.23E-01	Multiple Sources
Methyl Mercury	4.46	Grapentine *et al.,* 2003
Nickel	3.40E-02	ORNL, 1998
Selenium	6.26E-01	Welsh and Maughan, 1993
Silver	NA	No Data Available
Thallium	NA	No Data Available
Tin (Inorganic)	NA	No Data Available
Vanadium	1.48E-02	Multiple References
Zinc	5.69E-01	ORNL, 1998

Antimony

The BSAF for antimony is 0.0113 mg/kg wet-tissue/mg/kg dry sediment. This value is based Haus *et al.* (2007) who investigated concentrations of antimony in sediments and macroinvertebrates (amphipods and isopods, n=9) from eight sites in the Ruhr District of Germany, including ponds, streams and rivers. The value of 0.0113 is the arithmetic mean. Because the BSAF is reported on a wet-weight basis, applying a dry fraction conversion factor of 0.24 was not necessary for antimony.

Arsenic

The BSAF for arsenic is 0.103. This value was derived from benthic invertebrate arsenic uptake models developed by the Oak Ridge National Laboratory (ORNL 1998). Because these models estimate concentrations based on a dry-weight basis, a dry-weight to wet-weight conversion factor of 0.24 was applied to the model result (Equation 17).

$$UP_{SBI(fw)} = (10^{(0.754 * \log(Csed) - 0.292)}) / C_{sed} * (0.24) \qquad \text{Equation 17}$$

Barium

The BSAF for barium is 0.137. This value was derived from concentrations of barium in sediment and invertebrates from nine streams in the Blackfoot river watershed, ID, reported by Hamilton *et al.* (2002), and from two sites on the Wolf river, WI, reported by Garn *et al.* (2001). The value of 0.137 is the geometric mean (n = 14) dry weight BSAF of 0.570 multiplied by a dry-weight to wet-weight conversion factor of 0.24.

Beryllium

The BSAF for beryllium is 0.132. This value was derived from concentrations of beryllium in sediment and invertebrates from nine streams in the Blackfoot river watershed, ID, reported by

Hamilton *et al.* (2002), and from two sites on the Wolf river, WI, reported by Garn *et al.* (2001). The value of 0.132 is the arithmetic mean (n = 6) dry weight BSAF of 0.550 multiplied by a dry-weight to wet-weight conversion factor of 0.24.

Boron

The BSAF for boron is 0.229. This value was derived from concentrations of boron in sediment and invertebrates from nine streams in the Blackfoot river watershed, ID, reported by Hamilton *et al.* (2002), and from two sites on the Wolf river, WI, reported by Garn *et al.* (2001). The value of 0.229 is the geometric mean (n = 14) dry weight BSAF of 0.954 multiplied by a dry-weight to wet-weight conversion factor of 0.24.

Cadmium

The BSAF for cadmium is 0.325. This value was derived from benthic invertebrate cadmium uptake models developed by the Oak Ridge National Laboratory (ORNL 1998). Because these models estimate concentrations based on a dry-weight basis, a dry-weight to wet-weight conversion factor of 0.24 was applied to the model result (Equation 18).

$$UP_{SBI(fw)} = (10^{(0.692 * \log(Csed) + 0.0395)}) / C_{sed} * (0.24) \qquad \text{Equation 18}$$

Chromium (total)

The BSAF for chromium is 0.0727. This value was derived from benthic invertebrate chromium uptake models developed by the Oak Ridge National Laboratory (ORNL 1998). Because these models estimate concentrations based on a dry-weight basis, a dry-weight to wet-weight conversion factor of 0.24 was applied to the model result (Equation 19).

$$UP_{SBI(fw)} = (10^{(0.365 * \log(Csed) + 0.2092)}) / C_{sed} * (0.24) \qquad \text{Equation 19}$$

Chromium (Hexavalent)

A BSAF was not calculated for chromium VI as this species of chromium is very rarely measured in the aquatic environment; even in only mildly oxidizing environments, this form of chromium is rapidly reduced (Martello *et al.* 2007). Furthermore, if ingested chromium VI is most likely reduced within the biota and would not bioaccumulate into avian and mammalian invertivores (Kimbrough *et al.* 1999). No BSAFs were reported in the literature, and no studies reported concentrations of chromium VI in both sediment or water, and aquatic biota.

Cobalt

The BSAF for cobalt is 0.002. This value is based Garn *et al.* (2001) who investigated concentrations of cobalt and other metals in sediments and caddisfly larvae from two sites over four years on the Wolf river, WI. The value of 0.002 is the arithmetic mean (n = 6) wet weight BSAF of 0.01 multiplied by a dry-weight to wet-weight conversion factor of 0.24.

Lead

The BSAF for lead is 0.0274. This value was derived from benthic invertebrate lead uptake models developed by the Oak Ridge National Laboratory (ORNL 1998). Because these models estimate

concentrations based on a dry-weight basis, a dry-weight to wet-weight conversion factor of 0.24 was applied to the model result (Equation 20).

$$UP_{SBI(fw)} = (10^{(0.801 * \log(Csed) - 0.776)}) / C_{sed} * (0.24) \qquad \text{Equation 20}$$

Mercury (Inorganic)

The BSAF for inorganic mercury is 0.123. This value is derived from reported mercury concentrations in sediment and benthic invertebrates based on various studies (Filion and Morin 2000; Jaagumagi and Persaud 1992 in Filion and Morin 2000; Grapentine *et al.* 2003; Garn *et al.,* 2001; Naimo *et al.,* 2000). This value of 0.123 is the geometric mean (n = 48) wet weight BSAF of 0.513 multiplied by a dry-weight to wet-weight conversion factor of 0.24.

Methyl Mercury

The BSAF for methyl mercury is 4.46. This value is derived from reported methyl mercury concentrations in sediment and benthic invertebrates (three taxa sampled) collected from 34 sampling stations along the Saint Lawrence river, ON (Grapentine *et al.* 2003). This value of 4.46 is the geometric mean (n = 19) wet weight BSAF of 18.58 multiplied by a dry-weight to wet-weight conversion factor of 0.24.

Nickel

The BSAF for nickel is 0.034. This value was derived from benthic invertebrate nickel uptake models developed by the Oak Ridge National Laboratory (ORNL 1998). Because these models estimate concentrations based on a dry-weight basis, a dry-weight to wet-weight conversion factor of 0.24 was applied to the model result (Equation 21). The BSAF is estimated from data gathered from depurated biota.

$$UP_{SBI(fw)} = (10^{(0.695 * \log(Csed) - 0.44)}) / C_{sed} * (0.24) \qquad \text{Equation 21}$$

Selenium

The BSAF for selenium is 0.626. This value was derived from reported concentrations of selenium in red swamp crayfish (*Precambarus clarki*) and sediment sampled from six locations in the vicinity of Cibola National Wildlife Refuge, AR (Welsh and Maughan 1993). The value of 0.626 is the geometric mean (n = 12) wet weight BSAF of 2.61 multiplied by a dry-weight to wet-weight conversion factor of 0.24.

Silver

A BSAF for silver could not be estimated based on a lack of adequate data available in scientific literature.

Thallium

A BSAF for thallium could not be estimated based on a lack of adequate data available in scientific literature.

Tin (Inorganic)

A BSAF for tin could not be estimated based on a lack of adequate data available in scientific literature.

Vanadium

The BSAF for vanadium is 0.015. This value was derived from concentrations of vanadium in sediment and invertebrates reported from several studies (Hamilton *et al.* 2002; Haus *et al.* 2007; and Garn *et al.* 2001). The value of 0.015 is the geometric mean (n = 24) wet weight BSAF of 0.061 multiplied by a dry-weight to wet-weight conversion factor of 0.24.

Zinc

The BSAF for zinc is 0.569. This value was derived from benthic invertebrate zinc uptake models developed by the Oak Ridge National Laboratory (ORNL 1998). Because these models estimate concentrations based on a dry-weight basis, a dry-weight to wet-weight conversion factor of 0.24 was applied to the model result (Equation 22).

$$UP_{SBI(fw)} = (10^{(0.208 * \log(Csed) + 1.80)}) / C_{sed} * (0.24) \qquad \text{Equation 22}$$

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