Derivation of Sediment Quality Criteria for Indigenous Water Use Protection

Arsenic

A traditional water use SQC **value of 4.1 mg/kg** was adopted from Quebec (DSEE) REL for Arsenic.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 4.1 mg/kg (Quebec DSEE) to a high of 120 mg/kg (Washington DSE)).

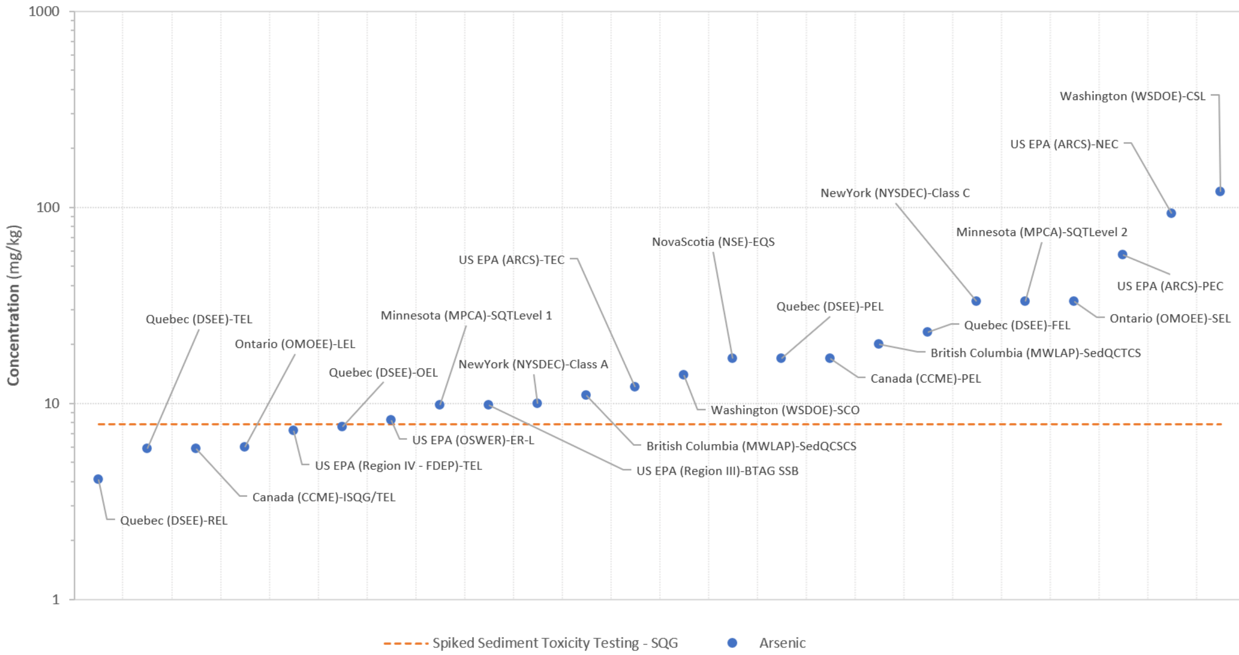

Figure 1. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots). The orange dashed line indicates a calculated value based on the CCME SST approach (7.8 mg/kg).*

SSTT Derivation

Spiked sediment toxicity values obtained from the Society of Environmental Toxicology and Chemistry (SETAC) Sediment Advisory Group (SEDAG) database (SEDAG 2016) were used to estimate a SQC based on CCME guidance (1995). The lowest of the lowest observed effect concentration (LOEC) values (39 mg/kg; *C. dilutes;* survival and growth) was multiplied by an Uncertainty Factor (UF) of 0.2. The calculated value of 7.8 mg/kg is in close agreement with the OEL value (7.6 mg/kg) provided by DSEE (2008). However, the data used to derive this SQC does not meet the minimum data-set requirements for derivation of a freshwater SQC for arsenic and confidence in this value is low.

Spiked Sediment Toxicity Testing Results - Arsenic

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Chironomus dilutus	juvenile	10	survival	NOEC	39	mg/kg	NA	7.4	Liber *et al.* 2011
Chironomus dilutus	juvenile	10	growth	NOEC	39	mg/kg	NA	7.4	Liber *et al.* 2011
Chironomus dilutus	**juvenile**	**10**	**growth**	**LOEC**	**39**	**mg/kg**	**NA**	**7.4**	**Liber *et al.* 2011**
Chironomus dilutus	juvenile	10	survival	LOEC	116	mg/kg	NA	7.4	Liber *et al.* 2011
Chironomus dilutus	juvenile	10	growth	LC25	174	mg/kg	NA	7.4	Liber *et al.* 2011
Chironomus dilutus	juvenile	10	growth	LC50	342	mg/kg	NA	7.4	Liber *et al.* 2011
Hyalella azteca	juvenile	10	survival	NOEC	462	mg/kg	NA	7.4	Liber *et al.* 2011
Hyalella azteca	juvenile	10	growth	NOEC	462	mg/kg	NA	7.4	Liber *et al.* 2011
Hyalella azteca	juvenile	10	growth	LC25	462	mg/kg	NA	7.4	Liber *et al.* 2011
Hyalella azteca	juvenile	10	growth	LC50	462	mg/kg	NA	7.4	Liber *et al.* 2011
Hyalella azteca	juvenile	10	survival	LC25	521	mg/kg	NA	7.4	Liber *et al.* 2011
Hyalella azteca	juvenile	10	survival	LC50	532	mg/kg	NA	7.4	Liber *et al.* 2011
Chironomus dilutus	juvenile	10	survival	LC50	642	mg/kg	NA	7.4	Liber *et al.* 2011
Chironomus dilutus	juvenile	10	survival	LC25	675	mg/kg	NA	7.4	Liber *et al.* 2011
Hyalella azteca	juvenile	10	survival	LOEC	724	mg/kg	NA	7.4	Liber *et al.* 2011
Hyalella azteca	juvenile	10	growth	LOEC	724	mg/kg	NA	7.4	Liber *et al.* 2011
		Derived guideline (LOEC*UF 0.2)			**7.8**	**mg/kg**			

Notes:
NA - not applicable
NOEC - no observed effect concentration
LOEC - lowest observed effect concentration
LC_{25} – 25% reduction in the endpoint (e.g. growth)
LC_{50} - 50% reduction in survival

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.9 (mg COPC / kg wet tissue per mg COPC / kg dry sediment). Arsenic appears to be bioaccumulated, through the ingestion of food, but is not biomagnified through food webs (Hepp *et al*., 2017).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also. A screening concentration of 21 mg/kg for humans and 43 mg/kg for ecological receptors was identified. It is understood that these values are reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were originally intended) but they are presented here as a simplified check function in effort to evaluate whether further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would inherently be protective of higher trophic organisms as well.

Summary

Results of the WoE analysis are provided in Table 3, below.

Table 3 **Arsenic WoE Evaluation**

Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Cadmium

A traditional water use SQC **value of 0.33 mg/kg** was selected for Cadmium based on the weight of evidence described below adopted from the Quebec (DEEM) REL.

Guideline Review

The literature review indicated that SQC values for cadmium ranged from a low of 0.33 mg/kg (indicating low potential for adverse effect) to a high of 44.1 mg/kg (concentration above which adverse effects are almost always expected to occur). Distribution of SQC values is visually depicted on Figure 2.

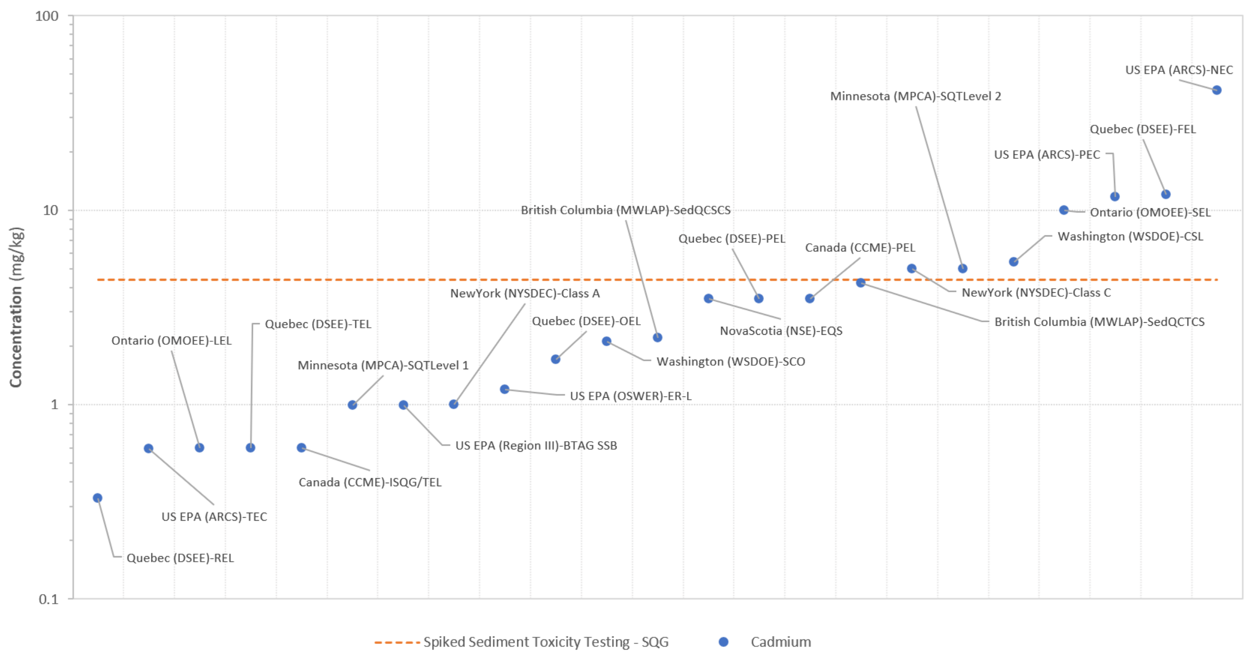

Figure 2. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots). The orange dashed line indicates a calculated value based on the CCME SST approach (4.4 mg/kg).*

SSTT Derivation

Spiked sediment toxicity values obtained from the Society of Environmental Toxicology and Chemistry (SETAC) Sediment Advisory Group (SEDAG) database (SEDAG 2016) were used to estimate a SQC based on CCME guidance (1995). Consistent with CCME (1995) the lowest of the LOEC values was multiplied by a UF of 0.2. The calculated value of 4.4 mg/kg is greater than the CCME-PEL value. This may reflect the difficulties associated with the NSTP approach as the CCME-PEL value is not a dose-response relationship.

Spiked Sediment Toxicity Testing Results - Cadmium

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Mercinaria mercinaria	juvenile	10	survival	LC50	1.66	mg/kg	NA	unspecified	Chung et al. 2007
Ampelisca verrili	unspecified	10	survival	LC50	4.8	mg/kg	NA	unspecified	Fulton et al. 1999
Rhepoxynius abronius	unspecified	10	survival	LC50	6.9	mg/kg	NA	unspecified	Swartz et al. 1985
Rhepoxynius abronius	adult	10	survival	LC50	9.8	mg/kg	NA	unspecified	Mearns et al. 1986
Ampelisca abdita	juvenile	10	survival	LC50	12	mg/kg	NA	unspecified	Fulton et al. 1999
Palaemonetes pugio	adult	10	survival	LC50	18.2	mg/kg	NA	unspecified	Fulton et al. 1999
Ampelisca abdita	unspecified	10	survival	NOEC	22	mg/kg	NA	0.95	Weston 1996
Ampelisca abdita	**unspecified**	**10**	**survival**	**LOEC**	**22**	**mg/kg**	**NA**	**0.95**	**Weston 1996**
Amphiascus tenuiremis	unspecified	4	survival	LC50	37.89	mg/kg	NA	unspecified	Green et al. 1993
Ampelisca abdita	unspecified	17	growth	NOEC	45	mg/kg	NA	0.95	Weston 1996
Amphiascus tenuiremis	adult	10	survival	LC50	45	mg/kg	NA	unspecified	Fulton et al. 1999
Hyalella azteca	juvenile	28	bioaccumulation	NOEC	47	mg/kg	NA	unspecified	Borgmann et al. 1991
Melita plumulosa	juvenile	42	bioaccumulation	LOEC	50	mg/kg	NA	unspecified	Gale et al. 2006
Hyalella azteca	juvenile	28	bioaccumulation	NOEC	62	mg/kg	NA	unspecified	Borgmann et al. 1991
Hyalella azteca	unspecified	10	survival	LC50	71.9	mg/kg	NA	2	Weston and Amweg 2007
Tellina deltoidalis	adult	10	survival	NOEC	75	mg/kg	NA	4.5	King et al. 2010
Hyalella azteca	juvenile	28	bioaccumulation	EC50	86	mg/kg	NA	unspecified	Borgmann et al. 1991
Hyalella azteca	juvenile	28	bioaccumulation	LOEC	87	mg/kg	NA	unspecified	Borgmann et al. 1991
Ampelisca abdita	unspecified	17	growth	LOEC	90	mg/kg	NA	0.95	Weston 1996
Ampelisca abdita	unspecified	17	survival	LC50	91	mg/kg	NA	0.95	Weston 1996
Hyalella azteca	juvenile	28	bioaccumulation	EC50	98	mg/kg	NA	unspecified	Borgmann et al. 1991
Ampelisca abdita	unspecified	17	growth	NOEC	110	mg/kg	NA	0.55	Weston 1996
Hyalella azteca	juvenile	10	survival	LC50	134	mg/kg	NA	1.7-2.1	Amweg and Weston 2007

Spiked Sediment Toxicity Testing Results - Cadmium									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Hyalella azteca	juvenile	28	bioaccumulation	LOEC	148	mg/kg	NA	unspecified	Borgmann et al. 1991
Ampelisca abdita	unspecified	10	survival	LC50	180	mg/kg	NA	0.95	Weston 1996
Melita plumulosa	adult	10	survival	NOEC	260	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	adult	10	survival	LOEC	260	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	adult	10	survival	LC50	260	mg/kg	NA	14	King et al. 2006b
Ampelisca abdita	unspecified	17	survival	NOEC	330	mg/kg	NA	0.55	Weston 1996
Ampelisca abdita	unspecified	17	growth	LOEC	330	mg/kg	NA	0.55	Weston 1996
Rhepoxynius abronius	unspecified	10	survival	LC50	479	mg/kg	NA	0.55	Weston 1996
Chaetocorophium cf. lucasi	unspecified	10	survival	NOEC	559	mg/kg	NA	unspecified	DeWitt et al. 1999
Melita plumulosa	juvenile	10	survival	NOEC	620	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	juvenile	42	growth	EC20	630	mg/kg	NA	unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	fertility	EC50	630	mg/kg	NA	unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	gravidity	EC50	630	mg/kg	NA	unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	survival	LC50	630	mg/kg	NA	unspecified	Gale et al. 2006
Ampelisca abdita	unspecified	17	survival	LC50	643	mg/kg	NA	0.55	Weston 1996
Melita plumulosa	juvenile	10	survival	LOEC	820	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	juvenile	10	growth	EC20	820	mg/kg	NA	unspecified	Gale et al. 2006
Melita plumulosa	juvenile	10	survival	LC50	820	mg/kg	NA	unspecified	Gale et al. 2006
Chaetocorophium cf. lucasi	unspecified	10	survival	LC50	833	mg/kg	NA	unspecified	DeWitt et al. 1999
Chaetocorophium cf. lucasi	unspecified	10	survival	LOEC	861	mg/kg	NA	unspecified	DeWitt et al. 1999
Eohaustorius estuarius	unspecified	10	survival	NOEC	1000	mg/kg	NA	0.55	Weston 1996
Eohaustorius estuarius	unspecified	10	survival	LOEC	1000	mg/kg	NA	0.55	Weston 1996
Ampelisca abdita	unspecified	17	survival	LOEC	1000	mg/kg	NA	0.55	Weston 1996
Eohaustorius estuarius	unspecified	10	survival	LC50	1000	mg/kg	NA	0.55	Weston 1996
Melita plumulosa	juvenile	10	survival	LC50	1630	mg/kg	NA	14	King et al. 2006b
Ampelisca abdita	adult	10	survival	LC50	2600	mg/kg	NA	unspecified	DiToro et al. 1990
			Derived guideline (LOEC*UF 0.2)		4.4				

Notes:
NA - not applicable

NOEC - no observed effect concentration

LOEC - lowest observed effect concentration

Spiked Sediment Toxicity Testing Results - Cadmium									
Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation

EC_{50} - 50% reduction in the endpoint (e.g. growth)

LC_{50} - 50 % reduction in survival to cadmium

The SSTT value exceeds the minimum data-set requirements for derivation of a freshwater SQC for cadmium and therefore confidence in this value is considered high.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 3.4 (mg COPC / kg wet tissue per mg COPC / kg dry sediment) indicating a potential for bioaccumulation. Cadmium is progressively enriched in epiphyte-based food-webs and has potential to biomagnify (Croteau *et al*., 2005) but does not generally biomagnify in aquatic ecosystems (Cardwell *et al.*, 2013).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 1.4 mg/kg for humans and 0.36 mg/kg for ecological receptors was identified. It is understood that these values are reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were intended). They are presented here as a simplified check function in effort to evaluate whether further consideration of these exposure pathways is warranted. In addressing sediments contaminated by cadmium additional consideration should be given to the potential that adverse effects may occur in higher trophic organisms (*i.e.,* both human and ecological receptors).

Summary

Results of the WoE analysis are provided are provided in Table 4, below.

Table 4 Cadmium WoE Evaluation

Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is measured at concentrations equivalent to or lower than reference stations.

Chromium (total)

A traditional water use SQC **value of 25 mg/kg** was selected for chromium based on the weight of evidence described below adopted from the Quebec (DEEM) REL.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 25 mg/kg (indicating low potential for adverse effect) to a high of 312 mg/kg (concentration above which adverse effects are almost always expected to occur). Distribution of SQC values is visually depicted on Figure 3 and summarized in Appendix A (Table 1).

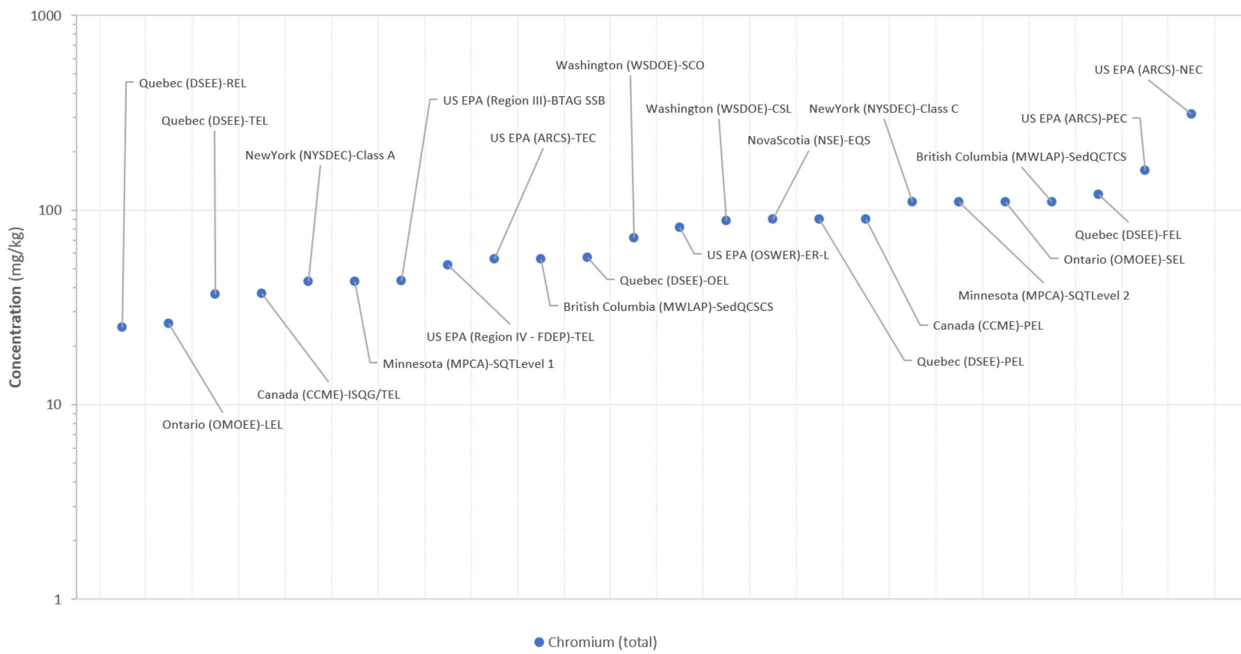

Figure 3. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified within the SETAC-SEDAG database (SEDAG 2016) for chromium.

A comparative check value of 220 mg/kg was identified in literature (potential for chromium to cause adverse effect to humans (total and trivalent chromium). Two sperate screening concentrations were identified for ecological receptors and these were 26 mg/kg (trivalent) and 130 mg/kg (hexavalent). It is understood that these values are reflective of terrestrial receptors and exposure scenarios (for which these guidelines were intended) but they are presented here as a simplified check function regarding whether further consideration of these exposure pathways is warranted. In addressing sediments contaminated by chromium consideration should be given to the potential for adverse effects to occur in higher trophic level ecological receptors.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.39 (mg COPC / kg wet tissue per mg COPC / kg dry sediment). There is no significant biomagnification of chromium in aquatic food webs (ATSDR 1993).

A comparative check value of 220 mg/kg was identified in literature (potential for chromium to cause adverse effect to humans (total and trivalent chromium. Two separate screening concentrations were identified for ecological receptors and these were 26 mg/kg (trivalent) and 130 mg/kg (hexavalent). It is understood that these values are reflective of terrestrial receptors and exposure scenarios (for which these guidelines were intended) but they are presented here as a simplified check function regarding whether further consideration of these exposure pathways is warranted. In addressing sediments contaminated by chromium consideration should be given to the potential for adverse effects to occur in higher trophic level ecological receptors.

Summary

Results of the WoE analysis are provided in Table 5, below.

Table 5	Chromium (Total) WoE Evaluation
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Copper

A traditional water use SQC **value of 8.6 mg/kg** was derived from available spiked sediment toxicity data.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 16 mg/kg (indicating low potential for adverse effect) to 1,200 mg/kg (concentration above which adverse effects are almost always expected to occur). Distribution of SQC values is visually depicted on Figure 4.

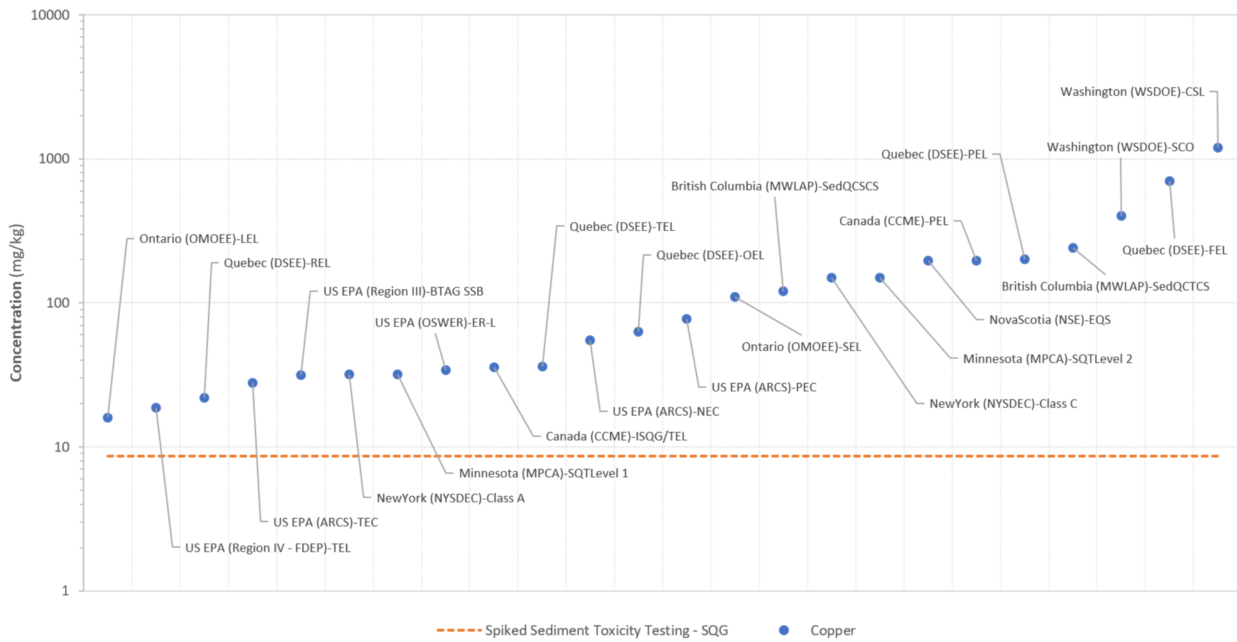

Figure 4. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots). The orange dashed line indicates a calculated SQC value based on the CCME SST approach (8.6 mg/kg).*

SSTT Derivation

Spiked sediment toxicity values used in derivation of the copper SST benchmarkwere obtained from the SETAC-SEDAG database (SEDAG 2016). Consistent with CCME (1995) the lowest of the lowest observed effect concentration (LOEC) values was multiplied by an Uncertainty Factor (UF) of 0.2. The calculated value of 8.6 mg/kg is lower than any of jurisdictions reviewed. This may reflect the difficulties associated with the NSTP approach as the Ontario-LEL, US EPA TEL/TEC, Quebec-REL and CCME-ISQC/TEL values are not based on dose-response relationships. The SST benchmark value exceeds the minimum data-set requirements for derivation of a freshwater SQC for copper and therefore confidence in this value is considered high.

Table B3: Spiked Sediment Toxicity Testing Results - Copper

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Gammarus locusta	Unspecified	10	survival	LC50	6.8	mg/kg	NA	Unspecified	Costa et al. 1996
Gammarus locusta	juvenile	10	survival	LC50	7	mg/kg	NA	Unspecified	Costa et al. 1998
Melita plumulosa	adult	11	reproduction	EC10	11	mg/kg	NA	0.4	Campana et al. 2012
Tellina deltoidalis	Unspecified	41	growth	EC10	15	mg/kg	NA	0.8	Campana et al. 2013
Tellina deltoidalis	Unspecified	41	growth	NOEC	17	mg/kg	NA	2.3	Campana et al. 2013
Gammarus locusta	juvenile	10	survival	LC50	18	mg/kg	NA	1	Correia 2000
Nitocra spinipes	adult	10	reproduction	NOEC	19	mg/kg	NA	0.4	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	EC10	20	mg/kg	NA	0.4	Campana et al. 2012
Tellina deltoidalis	Unspecified	41	growth	EC20	23	mg/kg	NA	0.8	Campana et al. 2013
Nitocra spinipes	adult	10	reproduction	EC20	24	mg/kg	NA	0.4	Campana et al. 2012
Ampelisca abdita	adult	10	survival	LC50	29.9	mg/kg	NA	0.78	Anderson et al. 2008
Chironomus riparius	larvae	28	emergence	EC10	33.3	mg/kg	NA	2.6	Roman et al. 2007
Nitocra spinipes	adult	10	reproduction	EC50	37	mg/kg	NA	0.4	Campana et al. 2012
Corophium volutator	adult	10	survival	LC50	37	mg/kg	NA	Unspecified	Bat et al. 1998
Tellina deltoidalis	Unspecified	41	growth	NOEC	38	mg/kg	NA	0.8	Campana et al. 2013
Melita plumulosa	adult	11	reproduction	EC10	39	mg/kg	NA	0.7	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	EC10	40	mg/kg	NA	0.7	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	EC10	41	mg/kg	NA	0.5	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	NOEC	43	mg/kg	NA	0.4	Campana et al. 2012
Nitocra spinipes	**adult**	**10**	**reproduction**	**LOEC**	**43**	**mg/kg**	**NA**	**0.4**	**Campana et al. 2012**

Table B3: Spiked Sediment Toxicity Testing Results - Copper

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Tellina deltoidalis	Unspecified	41	growth	EC10	43	mg/kg	NA	2.3	Campana et al. 2013
Tubifex tubifex	adult	28	growth	EC10	43.3	mg/kg	NA	2.6	Roman et al. 2007
Melita plumulosa	adult	11	reproduction	EC20	44	mg/kg	NA	0.4	Campana et al. 2012
Tellina deltoidalis	Unspecified	41	growth	EC50	46	mg/kg	NA	0.8	Campana et al. 2013
Nitocra spinipes	adult	10	reproduction	NOEC	50	mg/kg	NA	0.7	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	NOEC	50	mg/kg	NA	0.7	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	EC10	53	mg/kg	NA	0.5	Campana et al. 2012
Hyalella azteca	juvenile	28	growth	NOEC	53.2	mg/kg	NA	2.6	Roman et al. 2007
Paracorophium excavatum	adult	10	survival	LC50	55	mg/kg	NA	Unspecified	Mardsen and Wong 2001
Melita plumulosa	adult	11	reproduction	EC20	58	mg/kg	NA	0.7	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	NOEC	59	mg/kg	NA	1.5	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	NOEC	59	mg/kg	NA	1.5	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	EC20	59	mg/kg	NA	0.7	Campana et al. 2012
Chironomus riparius	larvae	28	emergence	EC50	59.2	mg/kg	NA	2.6	Roman et al. 2007
Chironomus riparius	larvae	28	emergence	NOEC	59.5	mg/kg	NA	2.6	Roman et al. 2007
Melita plumulosa	adult	11	reproduction	EC50	61	mg/kg	NA	0.4	Campana et al. 2012
Tellina deltoidalis	Unspecified	41	survival	NOEC	63	mg/kg	NA	0.8	Campana et al. 2013
Tellina deltoidalis	**Unspecified**	**41**	**growth**	**LOEC**	**63**	**mg/kg**	**NA**	**0.8**	**Campana et al. 2013**
Ampelisca abdita	adult	10	survival	LC50	66.6	mg/kg	NA	0.78	Anderson et al. 2008
Melita plumulosa	adult	11	reproduction	LOEC	68	mg/kg	NA	0.4	Campana et al. 2012
Lumbriculus variegatus	adult	28	biomass	EC10	69.6	mg/kg	NA	2.6	Roman et al. 2007
Gammarus pulex	juvenile	35	survival	LC10	73.2	mg/kg	NA	2.6	Roman et al. 2007
Hediste diversicolor	Unspecified	10	survival	LC50	74.988	mg/kg	NA	4	Mayor et al. 2008
Hyalella azteca	juvenile	28	growth	EC10	75.3	mg/kg	NA	2.6	Roman et al. 2007
Tubifex tubifex	adult	28	growth	NOEC	78.3	mg/kg	NA	2.6	Roman et al. 2007
Tubifex tubifex	adult	28	reproduction	NOEC	78.3	mg/kg	NA	2.6	Roman et al. 2007
Tellina deltoidalis	Unspecified	41	growth	EC20	79	mg/kg	NA	2.3	Campana et al. 2013
Tubifex tubifex	adult	28	reproduction	EC10	79.2	mg/kg	NA	2.6	Roman et al. 2007
Melita plumulosa	adult	11	reproduction	EC20	80	mg/kg	NA	0.5	Campana et al. 2012
Lumbriculus variegatus	adult	28	biomass	NOEC	80.5	mg/kg	NA	2.6	Roman et al. 2007
Lumbriculus variegatus	adult	28	reproduction	NOEC	80.5	mg/kg	NA	2.6	Roman et al. 2007
Melita plumulosa	adult	11	reproduction	LOEC	84	mg/kg	NA	0.7	Campana et al. 2012

Table B3: Spiked Sediment Toxicity Testing Results - Copper									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Nitocra spinipes	adult	10	reproduction	LOEC	85	mg/kg	NA	0.7	Campana et al. 2012
Tubifex tubifex	adult	28	reproduction	EC10	85.5	mg/kg	NA	2.6	Roman et al. 2007
Ampelisca abdita	adult	10	survival	LC50	85.5	mg/kg	NA	0.78	Anderson et al. 2008
Chironomus riparius	larvae	28	growth	NOEC	89.2	mg/kg	NA	2.6	Roman et al. 2007
Chironomus riparius	larvae	28	emergence	LOEC	89.2	mg/kg	NA	2.6	Roman et al. 2007
Nitocra spinipes	adult	10	reproduction	EC10	90	mg/kg	NA	1.5	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	EC10	91	mg/kg	NA	1.5	Campana et al. 2012
Chironomus riparius	larvae	28	growth	EC10	92.5	mg/kg	NA	2.6	Roman et al. 2007
Tellina deltoidalis	Unspecified	41	growth	EC10	94	mg/kg	NA	3.3	Campana et al. 2013
Gammarus pulex	juvenile	35	survival	NOEC	94.7	mg/kg	NA	2.6	Roman et al. 2007
Gammarus pulex	juvenile	35	growth	NOEC	94.7	mg/kg	NA	2.6	Roman et al. 2007
Hyalella azteca	juvenile	28	growth	LOEC	95.4	mg/kg	NA	2.6	Roman et al. 2007
Lumbriculus variegatus	adult	28	reproduction	EC10	96.9	mg/kg	NA	2.6	Roman et al. 2007
Tubifex tubifex	adult	28	reproduction	EC50	98	mg/kg	NA	2.6	Roman et al. 2007
Hyalella azteca	juvenile	28	survival	NOEC	100	mg/kg	NA	2.6	Roman et al. 2007
Tubifex tubifex	adult	28	growth	LOEC	102	mg/kg	NA	2.6	Roman et al. 2007
Tubifex tubifex	adult	28	reproduction	LOEC	102	mg/kg	NA	2.6	Roman et al. 2007
Gammarus pulex	juvenile	35	growth	EC10	102	mg/kg	NA	2.6	Roman et al. 2007
Nitocra spinipes	adult	10	reproduction	EC20	102	mg/kg	NA	0.5	Campana et al. 2012
Lumbriculus variegatus	adult	28	biomass	LOEC	103	mg/kg	NA	2.6	Roman et al. 2007
Lumbriculus variegatus	adult	28	reproduction	LOEC	103	mg/kg	NA	2.6	Roman et al. 2007
Lumbriculus variegatus	adult	28	reproduction	EC50	105	mg/kg	NA	2.6	Roman et al. 2007
Melita plumulosa	adult	11	reproduction	EC10	111	mg/kg	NA	3.8	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	EC50	111	mg/kg	NA	0.7	Campana et al. 2012
Tubifex tubifex	adult	28	reproduction	EC50	113	mg/kg	NA	2.6	Roman et al. 2007
Lumbriculus variegatus	adult	28	survival	NOEC	114	mg/kg	NA	2.6	Roman et al. 2007
Nitocra spinipes	adult	10	reproduction	EC10	114	mg/kg	NA	3.1	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	EC20	122	mg/kg	NA	1.5	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	EC20	123	mg/kg	NA	1.5	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	EC50	126	mg/kg	NA	0.7	Campana et al. 2012
Tubifex tubifex	adult	28	growth	EC50	126	mg/kg	NA	2.6	Roman et al. 2007
Lumbriculus variegatus	adult	28	biomass	EC50	126	mg/kg	NA	2.6	Roman et al. 2007

Table B3: Spiked Sediment Toxicity Testing Results - Copper									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Lumbriculus variegatus	adult	28	survival	LC10	126	mg/kg	NA	2.6	Roman et al. 2007
Tellina deltoidalis	Unspecified	41	growth	LOEC	133	mg/kg	NA	2.3	Campana et al. 2013
Hyalella azteca	juvenile	28	survival	LC10	135	mg/kg	NA	2.6	Roman et al. 2007
Tubifex tubifex	adult	28	survival	NOEC	138	mg/kg	NA	2.6	Roman et al. 2007
Lumbriculus variegatus	adult	28	survival	LOEC	140	mg/kg	NA	2.6	Roman et al. 2007
Melita plumulosa	adult	11	reproduction	EC10	146	mg/kg	NA	3.1	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	EC10	146	mg/kg	NA	7.4	Campana et al. 2012
Gammarus pulex	juvenile	35	growth	EC50	148	mg/kg	NA	2.6	Roman et al. 2007
Chironomus riparius	larvae	28	growth	EC50	150	mg/kg	NA	2.6	Roman et al. 2007
Chironomus riparius	larvae	28	survival	LC10	150	mg/kg	NA	2.6	Roman et al. 2007
Gammarus pulex	juvenile	35	survival	LC50	151	mg/kg	NA	2.6	Roman et al. 2007
Tellina deltoidalis	Unspecified	41	growth	EC20	157	mg/kg	NA	3.3	Campana et al. 2013
Tubifex tubifex	adult	28	survival	LOEC	158	mg/kg	NA	2.6	Roman et al. 2007
Gammarus locusta	juvenile	10	survival	LC50	159	mg/kg	NA	2	Correia 2000
Tubifex tubifex	adult	28	survival	LC10	160	mg/kg	NA	2.6	Roman et al. 2007
Tellina deltoidalis	Unspecified	41	survival	LOEC	170	mg/kg	NA	0.8	Campana et al. 2013
Gammarus pulex	juvenile	35	survival	LOEC	176	mg/kg	NA	2.6	Roman et al. 2007
Gammarus pulex	juvenile	35	growth	LOEC	176	mg/kg	NA	2.6	Roman et al. 2007
Chironomus riparius	larvae	28	survival	NOEC	180	mg/kg	NA	2.6	Roman et al. 2007
Hyalella azteca	juvenile	28	survival	LOEC	180	mg/kg	NA	2.6	Roman et al. 2007
Chironomus riparius	larvae	28	survival	LOEC	180	mg/kg	NA	2.6	Roman et al. 2007
Nitocra spinipes	adult	10	reproduction	EC10	180	mg/kg	NA	3.8	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	LOEC	188	mg/kg	NA	1.5	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	LOEC	188	mg/kg	NA	1.5	Campana et al. 2012
Chironomus riparius	larvae	28	growth	LOEC	188	mg/kg	NA	2.6	Roman et al. 2007
Corophium volutator	Unspecified	10	survival	LC50	193.326	mg/kg	NA	4	Mayor et al. 2008
Melita plumulosa	adult	11	reproduction	EC20	194	mg/kg	NA	3.8	Campana et al. 2012
Hyalella azteca	juvenile	28	growth	EC50	194	mg/kg	NA	2.6	Roman et al. 2007
Melita plumulosa	adult	11	reproduction	EC50	196	mg/kg	NA	0.5	Campana et al. 2012
Melita plumulosa	juvenile	10	survival	LC50	198	mg/kg	NA	3.3	Strom et al. 2011
Nitocra spinipes	adult	10	reproduction	EC20	199	mg/kg	NA	3.1	Campana et al. 2012
Lumbriculus variegatus	adult	28	survival	LC50	211	mg/kg	NA	2.6	Roman et al. 2007

Table B3: Spiked Sediment Toxicity Testing Results - Copper									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Tellina deltoidalis	Unspecified	41	growth	NOEC	212	mg/kg	NA	3.3	Campana et al. 2013
Melita plumulosa	juvenile	10	survival	LC50	212	mg/kg	NA	2.1	Strom et al. 2011
Tellina deltoidalis	Unspecified	41	growth	EC50	228	mg/kg	NA	2.3	Campana et al. 2013
Melita plumulosa	adult	11	reproduction	EC20	232	mg/kg	NA	7.4	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	NOEC	236	mg/kg	NA	3.1	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	LOEC	236	mg/kg	NA	3.1	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	EC50	238	mg/kg	NA	1.5	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	EC10	248	mg/kg	NA	7.4	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	EC50	251	mg/kg	NA	0.5	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	EC50	275	mg/kg	NA	1.5	Campana et al. 2012
Amphiascus tenuiremis	adult	4	survival	LC50	281.9	mg/kg	NA	2.77	Hagopian-Schlekat et al. 2001
Melita plumulosa	juvenile	42	fertility	EC50	290	mg/kg	NA	Unspecified	Gale et al. 2006
Hyalella azteca	juvenile	28	survival	LC50	316	mg/kg	NA	2.6	Roman et al. 2007
Chironomus riparius	larvae	28	survival	LC50	320	mg/kg	NA	2.6	Roman et al. 2007
Tubifex tubifex	adult	28	survival	LC50	327	mg/kg	NA	2.6	Roman et al. 2007
Melita plumulosa	juvenile	42	fertility	EC50	328	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	fertility	EC50	330	mg/kg	NA	Unspecified	Gale et al. 2006
Nitocra spinipes	adult	10	reproduction	EC20	333	mg/kg	NA	3.8	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	NOEC	337	mg/kg	NA	0.5	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	NOEC	337	mg/kg	NA	0.5	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	LOEC	337	mg/kg	NA	0.5	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	LOEC	337	mg/kg	NA	0.5	Campana et al. 2012
Melita plumulosa	juvenile	42	bioaccumulation	LOEC	350	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	growth	EC20	350	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	gravidity	EC50	350	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	survival	LC50	350	mg/kg	NA	Unspecified	Gale et al. 2006
Eohaustorius estuarius	adult	10	survival	LC50	355	mg/kg	NA	0.78	Anderson et al. 2008
Tellina deltoidalis	Unspecified	41	growth	EC50	373	mg/kg	NA	3.3	Campana et al. 2013
Tellina deltoidalis	Unspecified	41	growth	LOEC	391	mg/kg	NA	3.3	Campana et al. 2013
Tellina deltoidalis	adult	10	survival	LC50	391	mg/kg	NA	3.3	Strom et al. 2011
Gammarus locusta	juvenile	10	survival	NOEC	402	mg/kg	NA	4	Correia 2000

Table B3: Spiked Sediment Toxicity Testing Results - Copper

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Melita plumulosa	juvenile	42	gravidity	EC50	410	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	growth	EC20	420	mg/kg	NA	Unspecified	Gale et al. 2006
Tellina deltoidalis	Unspecified	41	survival	NOEC	433	mg/kg	NA	2.3	Campana et al. 2013
Tellina deltoidalis	Unspecified	41	survival	LOEC	433	mg/kg	NA	2.3	Campana et al. 2013
Nitocra spinipes	adult	10	reproduction	EC20	436	mg/kg	NA	7.4	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	EC50	445	mg/kg	NA	3.8	Campana et al. 2012
Tellina deltoidalis	adult	10	survival	LC50	455	mg/kg	NA	2.1	Strom et al. 2011
Melita plumulosa	adult	11	reproduction	NOEC	456	mg/kg	NA	3.1	Campana et al. 2012
Melita plumulosa	juvenile	10	survival	NOEC	460	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	adult	11	reproduction	EC20	475	mg/kg	NA	3.1	Campana et al. 2012
Melita plumulosa	juvenile	10	survival	LC10	490	mg/kg	NA	4	Simpson et al. 2012
Melita plumulosa	adult	11	reproduction	EC50	491	mg/kg	NA	7.4	Campana et al. 2012
Hyale longicornis	Unspecified	10	survival	NOEC	500	mg/kg	NA	4-5	Simpson et al. 2011
Eohaustorius estuarius	adult	10	survival	LC50	522	mg/kg	NA	0.78	Anderson et al. 2008
Melita plumulosa	juvenile	42	survival	LC50	530	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	adult	10	survival	NOEC	550	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	adult	10	survival	LOEC	550	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	juvenile	10	survival	LC10	560	mg/kg	NA	4	Simpson et al. 2012
Melita plumulosa	juvenile	10	survival	LC20	570	mg/kg	NA	4	Simpson et al. 2012
Spisula trigonella	adult	10	survival	LC50	582	mg/kg	NA	3.3	Strom et al. 2011
Hyale longicornis	Unspecified	10	survival	LC20	610	mg/kg	NA	4-5	Simpson et al. 2011
Melita plumulosa	adult	11	reproduction	NOEC	675	mg/kg	NA	3.8	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	NOEC	675	mg/kg	NA	3.8	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	LOEC	675	mg/kg	NA	3.8	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	LOEC	675	mg/kg	NA	3.8	Campana et al. 2012
Melita plumulosa	juvenile	10	survival	LC10	680	mg/kg	NA	4	Simpson et al. 2012
Melita plumulosa	juvenile	10	survival	LC20	690	mg/kg	NA	4	Simpson et al. 2012
Melita plumulosa	adult	11	reproduction	NOEC	706	mg/kg	NA	7.4	Campana et al. 2012
Nitocra spinipes	adult	10	reproduction	NOEC	706	mg/kg	NA	7.4	Campana et al. 2012
Melita plumulosa	adult	11	reproduction	LOEC	706	mg/kg	NA	7.4	Campana et al. 2012

Table B3: Spiked Sediment Toxicity Testing Results - Copper									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Nitocra spinipes	adult	10	reproduction	LOEC	706	mg/kg	NA	7.4	Campana et al. 2012
Spisula trigonella	adult	10	survival	LC50	708	mg/kg	NA	2.1	Strom et al. 2011
Melita plumulosa	adult	11	reproduction	EC50	720	mg/kg	NA	3.1	Campana et al. 2012
Eohaustorius estuarius	adult	10	survival	LC50	726	mg/kg	NA	0.78	Anderson et al. 2008
Melita plumulosa	juvenile	10	survival	LC50	730	mg/kg	NA	4	Simpson et al. 2012
Nitocra spinipes	adult	10	reproduction	EC50	740	mg/kg	NA	3.1	Campana et al. 2012
Melita plumulosa	juvenile	10	survival	LC50	770	mg/kg	NA	Unspecified	Gale et al. 2006
Tellina deltoidalis	Unspecified	41	survival	NOEC	776	mg/kg	NA	3.3	Campana et al. 2013
Tellina deltoidalis	Unspecified	41	survival	LOEC	776	mg/kg	NA	3.3	Campana et al. 2013
Nitocra spinipes	adult	10	reproduction	EC50	778	mg/kg	NA	3.8	Campana et al. 2012
Melita plumulosa	juvenile	10	survival	LC50	790	mg/kg	NA	14	King et al. 2006b
Nitocra spinipes	Unspecified	5	survival	NOEC	800	mg/kg	NA	Unspecified	Perez et al. 2011
Melita plumulosa	juvenile	42	survival	LC50	800	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	adult	11	reproduction	LOEC	806	mg/kg	NA	3.1	Campana et al. 2012
Melita plumulosa	juvenile	10	survival	LC50	806	mg/kg	NA	4.5	Strom et al. 2011
Melita plumulosa	juvenile	10	survival	LC20	810	mg/kg	NA	4	Simpson et al. 2012
Melita plumulosa	juvenile	10	survival	LOEC	820	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	juvenile	10	survival	LC50	970	mg/kg	NA	4	Simpson et al. 2012
Tellina deltoidalis	adult	10	survival	LC50	980	mg/kg	NA	4.5	Strom et al. 2011
Spisula trigonella	adult	10	survival	LC50	997	mg/kg	NA	4.5	Strom et al. 2011
Corophium sp	adult	10	survival	LC50	999	mg/kg	NA	Unspecified	Hyne and Everett 1998
Nitocra spinipes	Unspecified	5	survival	LOEC	1000	mg/kg	NA	Unspecified	Perez et al. 2011
Hyale longicornis	Unspecified	10	survival	LOEC	1000	mg/kg	NA	4-5	Simpson et al. 2011
Melita plumulosa	juvenile	10	survival	LC10	1000	mg/kg	NA	4	Simpson et al. 2012
Hyale longicornis	Unspecified	10	survival	LC50	1030	mg/kg	NA	4-5	Simpson et al. 2011
Nitocra spinipes	adult	10	reproduction	EC50	1080	mg/kg	NA	7.4	Campana et al. 2012
Melita plumulosa	juvenile	10	survival	LC50	1100	mg/kg	NA	4	Simpson et al. 2012
Melita plumulosa	juvenile	10	growth	EC20	1140	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	10	survival	LC20	1150	mg/kg	NA	4	Simpson et al. 2012
Mysella anomala	Unspecified	10	survival	NOEC	1200	mg/kg	NA	Unspecified	King et al. 2004

Table B3: Spiked Sediment Toxicity Testing Results - Copper

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Corophium minor	Unspecified	10	survival	NOEC	1250	mg/kg	NA	4-5	Simpson et al. 2011
Nassarius burchardi	Unspecified	10	survival	NOEC	1250	mg/kg	NA	4-5	Simpson et al. 2011
Corophium minor	Unspecified	10	survival	LC10	1260	mg/kg	NA	4-5	Simpson et al. 2011
Australonereis ehlersi	Unspecified	10	survival	NOEC	1300	mg/kg	NA	Unspecified	King et al. 2004
Soletellina alba	Unspecified	10	survival	LOEC	1300	mg/kg	NA	Unspecified	King et al. 2004
Nephtys australiensis	Unspecified	10	survival	NOEC	1400	mg/kg	NA	Unspecified	King et al. 2004
Nassarius burchardi	Unspecified	10	survival	LC10	1450	mg/kg	NA	4-5	Simpson et al. 2011
Melita plumulosa	juvenile	10	survival	LC50	1460	mg/kg	NA	4	Simpson et al. 2012
Melita plumulosa	adult	10	survival	LC50	1520	mg/kg	NA	14	King et al. 2006b
Nassarius burchardi	Unspecified	10	survival	LC20	1550	mg/kg	NA	4-5	Simpson et al. 2011
Corophium minor	Unspecified	10	survival	LC20	1560	mg/kg	NA	4-5	Simpson et al. 2011
Nassarius burchardi	Unspecified	10	survival	LC50	1720	mg/kg	NA	4-5	Simpson et al. 2011
Corophium minor	Unspecified	10	survival	LOEC	1750	mg/kg	NA	4-5	Simpson et al. 2011
Nassarius burchardi	Unspecified	10	survival	LOEC	1750	mg/kg	NA	4-5	Simpson et al. 2011
Corophium minor	Unspecified	10	survival	LC50	1980	mg/kg	NA	4-5	Simpson et al. 2011
Heloecius cordiformis	Unspecified	10	survival	NOEC	2000	mg/kg	NA	4-5	Simpson et al. 2011
Nitocra spinipes	Unspecified	5	survival	LC50	2000	mg/kg	NA	Unspecified	Perez et al. 2011
			Derived guideline (LOEC*UF 0.2)		**8.6**				

Notes:

NA - not applicable

NOEC - no observed effect concentration

LOEC - lowest observed effect concentration

EC_{10} - 10% reduction in the endpoint (e.g. growth)

EC_{20}- 20% reduction in the endpoint (e.g. growth)

LC_{10} - 10% reduction in survival to copper

LC_{25} - 25% reduction in survival to copper

LC_{50} - 50% reduction in survival to copper

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Copper does not generally biomagnify in aquatic ecosystems (Cardwell *et al.* 2013). The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.3 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 1,100 mg/kg for humans and 28 mg/kg for ecological receptors was identified. It is understood that these values are reflective of terrestrial receptors and exposure scenarios (for which these guidelines were intended). They are presented here as a simplified check function regarding whether further consideration of these exposure pathways is warranted. In addressing sediments contaminated by copper consideration should be given to the potential for adverse effects to occur in higher trophic level ecological receptors.

Summary

Results of the WoE analysis are provided in Table 6, below.

Table 6	**Copper WoE Evaluation**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Lead

An overall screening **SQC value of 25 mg/kg** was selected for lead based on the Quebec (DSEE) REL.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 25 mg/kg (indicating low potential for adverse effect) to 1,300 mg/kg (concentration above which adverse effects are almost always expected to occur). Distribution of SQC values is visually depicted on Figure 5 and summarized in Table 1.

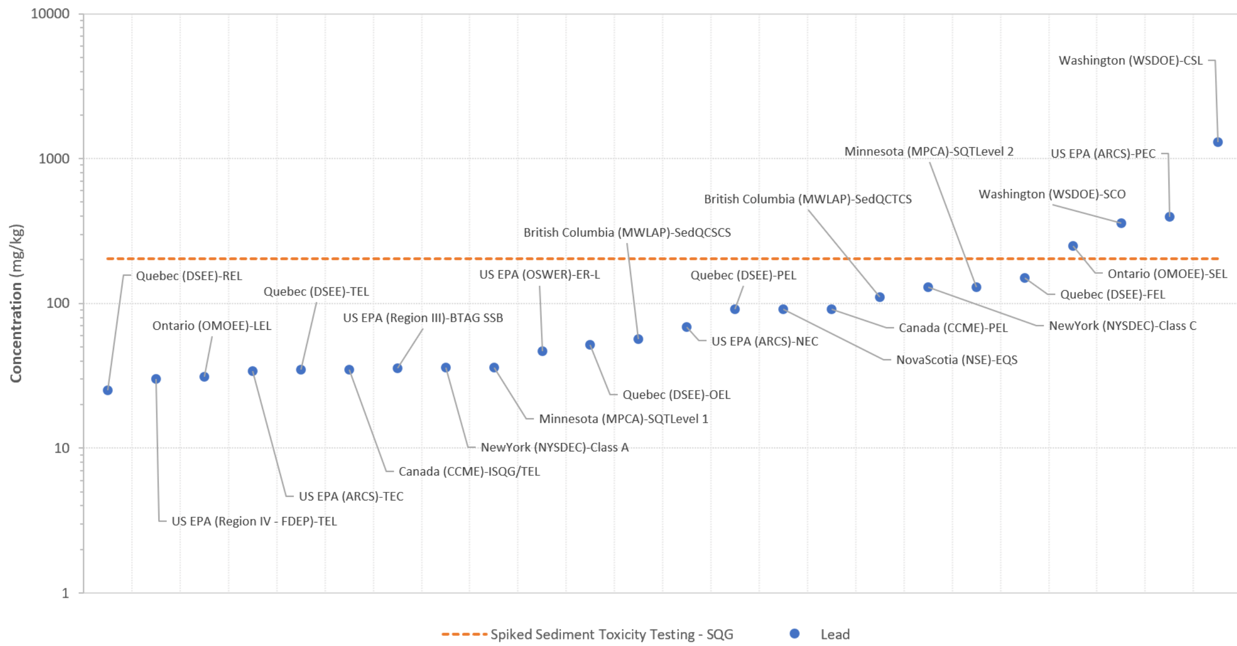

Figure 5. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots). The orange dashed line indicates a calculated SST benchmark value based on the CCME SST approach (204 mg/kg).*

SSTT Derivation

Spiked sediment toxicity values used in derivation of the lead SST benchmark were obtained from the SETAC-SEDAG database (SEDAG 2016). Consistent with CCME (1995) the lowest of the lowest observed effect concentration (LOEC) values was multiplied by an Uncertainty Factor (UF) of 0.2. The calculated value of 204 mg/kg is greater than the CCME-PEL value and the FEL value provided by DSEE (2008). This may reflect the difficulties associated with the NSTP approach as the Ontario-LEL, US EPA TEL/TEC, Quebec-REL and CCME-ISQC/TEL values are not based on dose-response relationships.

Spiked Sediment Toxicity Testing Results - Lead

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Hyalella azteca	juvenile	28	bioaccumulation	LC25	26.1	mg/kg	NA	3	Borgmann 1999
Hyalella azteca	juvenile	28	bioaccumulation	LC50	33.6	mg/kg	NA	3	Borgmann 1999
Melita plumulosa	juvenile	10	survival	NOEC	580	mg/kg	NA	14	King et al. 2006b
Leptocheirus plumulosus	juvenile	10	survival	NOEC	795	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	NOEC	795	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	NOEC	795	mg/kg	NA	0.64	Stanley et al. 2010
Tellina deltoidalis	adult	10	survival	NOEC	1000	mg/kg	NA	4.5	King et al. 2010
Melita plumulosa	juvenile	10	survival	LOEC	1020	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	juvenile	10	survival	LC50	1980	mg/kg	NA	14	King et al. 2006b
Amphiascus tenuiremis	adult	4	survival	LC50	2462	mg/kg	NA	2.77	Hagopian-Schlekat et al. 2001
Leptocheirus plumulosus	juvenile	10	survival	LC50	3295	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	LC50	3411	mg/kg	NA	0.64	Stanley et al. 2010
Melita plumulosa	adult	10	survival	NOEC	3560	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	adult	10	survival	LOEC	3560	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	adult	10	survival	LC50	3560	mg/kg	NA	14	King et al. 2006b
Hyalella azteca	juvenile	28	survival	LC25	3729	mg/kg	NA	3	Borgmann 1999
Leptocheirus plumulosus	juvenile	10	survival	LC50	3810	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	NOEC	3820	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	NOEC	3820	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	LOEC	3820	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	LOEC	3820	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	LOEC	3820	mg/kg	NA	0.64	Stanley et al. 2010

Spiked Sediment Toxicity Testing Results - Lead									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Leptocheirus plumulosus	juvenile	10	survival	LC50	3825	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	LC50	3969	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	LOEC	5260	mg/kg	NA	0.64	Stanley et al. 2010
Leptocheirus plumulosus	juvenile	10	survival	LOEC	5260	mg/kg	NA	0.64	Stanley et al. 2010
Hyalella azteca	juvenile	28	growth	EC25	6216	mg/kg	NA	3	Borgmann 1999
Hyalella azteca	juvenile	28	survival	LC50	6837	mg/kg	NA	3	Borgmann 1999
Hyalella azteca	juvenile	28	growth	EC50	18854	mg/kg	NA	3	Borgmann 1999
		Derived guideline (LOEC*UF 0.2)			204				

Notes:
NA - not applicable
NOEC - no observed effect concentration
LOEC - lowest observed effect concentration
EC_{10} - 10% reduction in the endpoint (e.g. growth)
EC_{20}- effect concentaiton to 20% of the test-species20% reduction in the endpoint (e.g. growth)
LC_{10} - 10% reduction in survival to lead
LC_{25} - 25% reduction in survival to lead
LC_{50} - 50% reduction in survival to lead

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Lead is unlikely to biomagnify in aquatic ecosystems (Cardwell *et al.* 2013). The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.63 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 140 mg/kg for humans and 11 mg/kg for ecological receptors was identified. It is understood that these values are reflective of terrestrial receptors and exposure scenarios (for which these guidelines were intended). They are presented here as a simplified check function regarding whether further consideration of these exposure pathways is warranted. In addressing sediments contaminated by lead consideration should be given to the potential for adverse effects to occur in higher trophic level ecological receptors and humans.

Given that the US EPA Eco-SSL value for the protection of avian insectivores is the lower than the available SQCs and the research on biomagnification of lead in food webs indicates low potential, it is recommended that lead concentrations in sediment and benthic invertebrates be monitored closely to determine bioaccumulation is occurring.

Summary

Results of the WoE analysis are provided in Table7, below.

Table 7	**SQC - Lead**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Manganese

A **SQC value of 460 mg/kg** was adopted from the Ontario MOE for manganese.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 460 mg/kg (SSB) (indicating low potential for adverse effect) to 1,673 mg/kg (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 6.

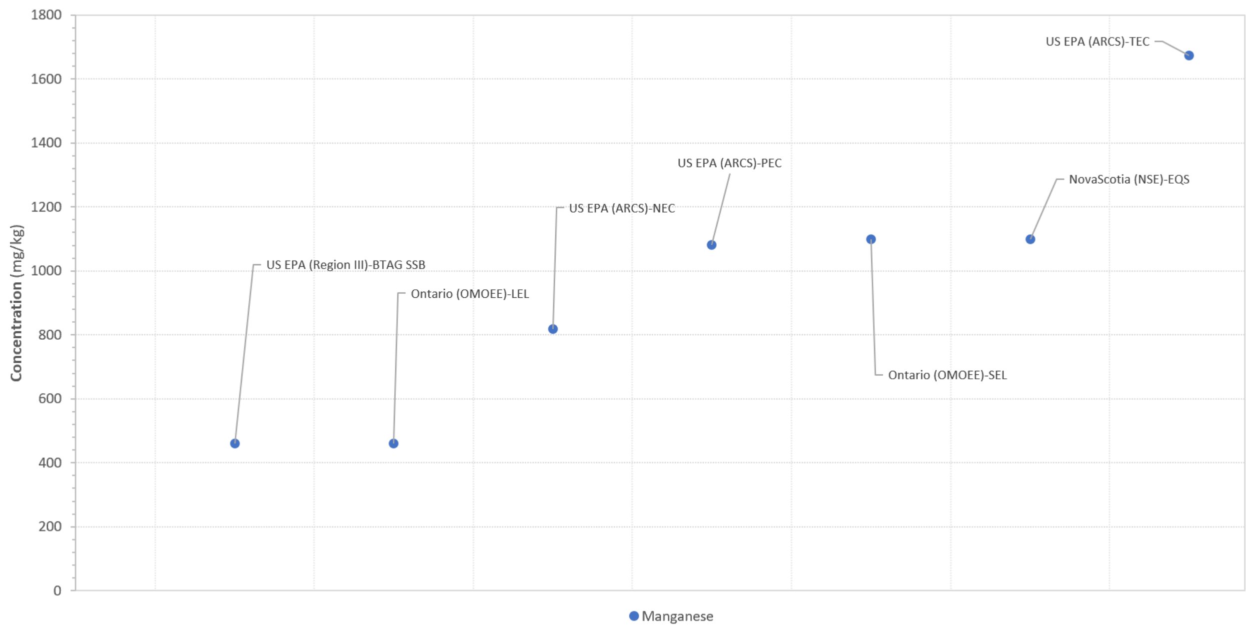

Figure 6. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified within the SETAC-SEDAG database (SEDAG 2016) for manganese.

Direct Soil Contact Receptors Check

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration was not identified for humans and value of 4,000 mg/kg was selected for protection of ecological receptors. It is understood that these values are reflective of terrestrial receptors and exposure scenarios (for which these guidelines were intended). They are presented here as a simplified check function regarding whether further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would inherently be protective of higher trophic organisms as well.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Manganese show limited to low potential for biomagnification in the aquatic ecosystems (World Health Organization (WHO) 2004). A sediment-to-benthic invertebrate bioconcentration factor was not reported by the US EPA (1999).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration was not identified for humans and value of 4,000 mg/kg was selected for protection of mammalian wildlife receptors, 450 for soil invertebrates and 220 for plants (US EPA 2007). It is understood that these values are reflective of terrestrial receptors and exposure scenarios (for which these guidelines were intended) but the values for invertebrates and plants are similar to the OMOE LEL and the check indicates the SQC is likely protective of lower trophic level health and preventing bioaccumulation. They are presented here as a simplified check function regarding whether further consideration of these exposure pathways is warranted.

It is considered likely that protection of the aquatic receptors (benthic invertebrates) would inherently be protective of higher trophic organisms as well.

Summary

Results of the WoE analysis are provided in Table 8, below.

Table 8	**Manganese WoE Evaluation**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Mercury

An overall screening **SQC value of 0.094 mg/kg** was selected from the Quebec (DSEE) REL for mercury. This value does not preclude the need to evaluate the potential for risk associated with bioconcentration of methyl-mercury in the food-web.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.094 mg/kg (REL) (indicating low potential for adverse effect) to 2.0 mg/kg (SEL) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 7 and summarized in Appendix A (Table 1).

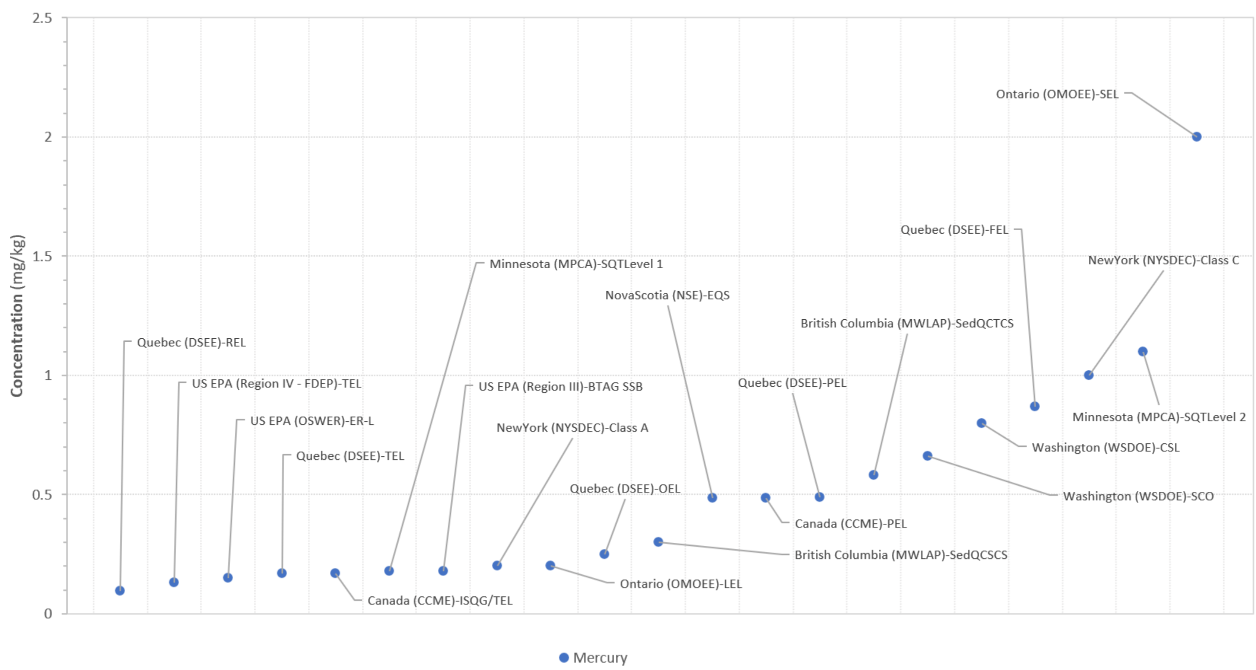

Figure 7. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were identified but are insufficient for derivation of an SST benchmark.

Spiked Sediment Toxicity Testing Results - Mercury									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Rhepoxynius abronius	adult	10	survival	LC10	11.4	mg/kg	NA	0.25	Swartz et al. 1988
Rhepoxynius abronius	adult	10	survival	LC50	13.1	mg/kg	NA	0.25	Swartz et al. 1988
Rhepoxynius abronius	adult	10	survival	LC50	15.2	mg/kg	NA	0.25	Swartz et al. 1988

Notes:
LC_{10} - 10% reduction in survival to mercury
LC_{50} - 50% reduction in survival to mercury

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Mercury (and in particular methyl-mercury) biomagnifies through the food web as predators eat other organisms and absorb the contaminants that their food sources contained (Government of Canada 2013). The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.068 for mercury and 0.48 for methyl mercury (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening value of 6.6 mg/kg was identified for humans. There were no direct contact values associated with ecological receptors. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would inherently be protective of the human direct contact exposure scenario as well.

Summary

Results of the WoE analysis are provided in Table 9, below.

Table 9	Mercury WoE Evaluation
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is measured at concentrations equivalent to or lower than reference stations.

Molybdenum

An overall screening **SQC value of 718 mg/kg** was derived using the SST benchmark approach for molybdenum.

However, the SST derived benchmark does not meet the minimum data-set requirements for derivation of a freshwater SQC for molybdenum as this result is sourced from a single study and therefore confidence in this value is low.

Guideline Review

No SQCs were identified for molybdenum.

SSTT Derivation

Data for two species from a single SST study was identified. Consistent with CCME (1995) the lowest of the lowest observed effect concentration (LOEC) values was multiplied by an Uncertainty Factor (UF) of 0.2. The calculated value of 717.8 mg/kg is the only referenced sediment guideline available for consideration.

Spiked Sediment Toxicity Testing Results - Molybdenum

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Chironomus dilutus	juvenile	10	survival	NOEC	3589	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	NOEC	3589	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	LOEC	3589	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	LOEC	3589	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	LC50	3589	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	LC50	3589	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	NOEC	3742	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	NOEC	3742	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	LOEC	3742	mg/kg	NA	7.4	Liber et al. 2011

Spiked Sediment Toxicity Testing Results - Molybdenum									
Hyalella azteca	juvenile	10	growth	LOEC	3742	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	LC25	3742	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	LC25	3742	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	LC25	3742	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	LC25	3742	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	LC50	3742	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	LC50	3742	mg/kg	NA	7.4	Liber et al. 2011
		Derived guideline (LOEC*UF 0.2)			717.8				

Notes:
NA - not applicable
NOEC - no observed effect concentration
LOEC - lowest observed effect concentration
EC_{10} - 10% reduction in the endpoint (e.g. growth)
EC_{20}- 20% reduction in the endpoint (e.g. growth)
LC_{10} - 10% reduction in survival to molybdenum
LC_{25} - 25% reduction in survival to molybdenum
LC_{50} - 50% reduction in survival to molybdenum

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Molybdenum is unlikely to biomagnify in aquatic ecosystems (Saiki *et al.* 1993). No sediment-to-benthic invertebrate bioconcentration factor were reported by the US EPA (1999).

No sediment-to-benthic invertebrate bioconcentration factor were reported by the US EPA (1999) for molybdenum.

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also. No values were identified from which to derive a either a human or wildlife screening value.

Summary

Results of the WoE analysis are provided in Table 10, below.

Table 10	Molybdenum WoE Evaluation
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Nickel

An overall screening **SQC value of 16 mg/kg** was selected for nickel based on the OMOE guideline.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 15.9 mg/kg (ER-L) (indicating low potential for adverse effect) to 110 mg/kg (CSL) (concentration above which adverse effects are almost always expected to occur).

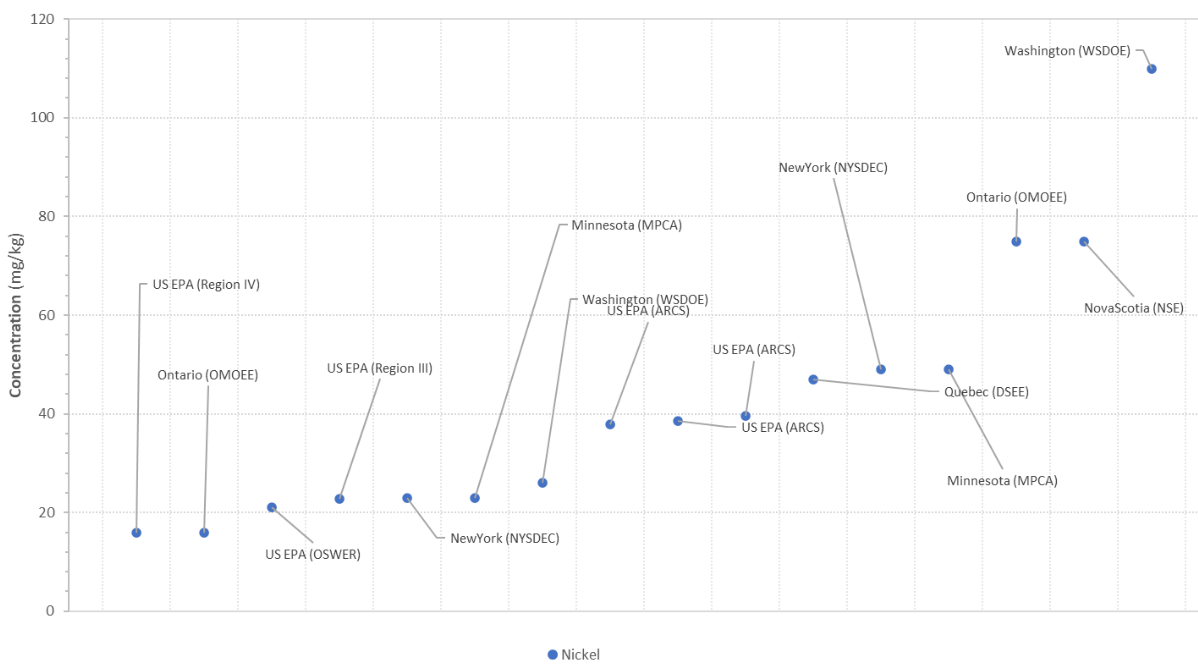

Figure 8. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified within the SETAC-SEDAG database (SEDAG 2016) for nickel.

Direct Soil Contact Receptors Check

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 200 mg/kg for humans and 130 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were intended). They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would inherently be protective of higher these higher trophic organisms as well.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Dumas and Hare (2008) demonstrated that nickel was assimilated by predatory alderflies (*Sialis velata*) feeding on aquatic invertebrates that had previously accumulated nickel from contaminated sediment, and indicated these metals are transferred along the aquatic food chain and that food is an important source for biomagnification.

The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.9 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

Summary

Results of the WoE analysis are provided provided in Table 11, below

Table 11	**SQC - Nickel**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is measured at concentrations equivalent to or lower than reference stations.

Selenium

An overall screening **SQC value of 2 mg/kg** from the Alberta ISQCs (adopted from BC 1992;2004) was selected for selenium.

This SQC does not consider selenium enrichment within aquatic food webs in lotic and lentic environments and additional monitoring in aquatic biota is required if selenium concentrations exceed the SQC.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 2.0 mg/kg (SSB) (indicating low potential for adverse effect) to 20 mg/kg (CSL) (concentration above which adverse effects are almost always expected to occur).

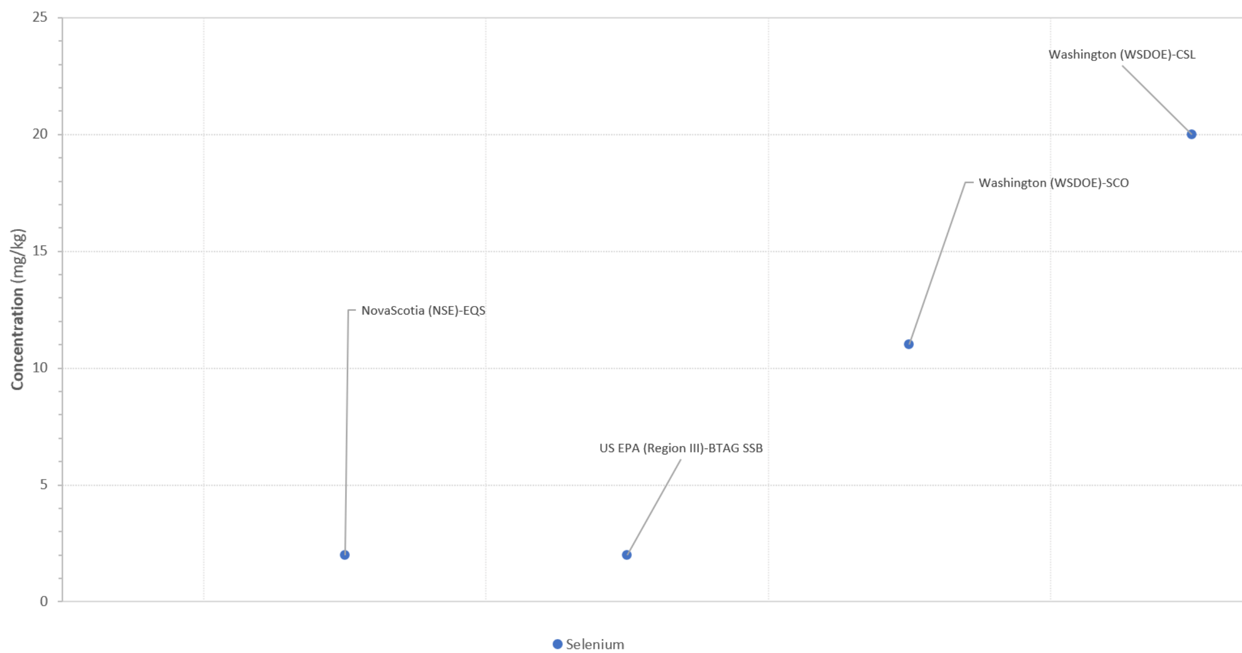

Figure 9. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified within the SETAC-SEDAG database (SEDAG 2016) for selenium.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Selenium has potential to biomagnify through the food web placing piscivorous fish and aquatic birds at greatest risk (Lemly and Smith 1990).

Several studies conducted in British Columbia's Elk Valley (an area of significant coal mining) have indicated the potential for risk of selenium biomagnification and trophic transfer potential in both lotic and lentic environments (Holmgren 2016).

The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.9 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 80 mg/kg for humans and 0.63 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were intended). They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. In addressing sediments contaminated by selenium consideration should be given to the potential that adverse effects may occur in higher trophic level wildlife receptors.

Summary

Results of the WoE analysis are provided in Table 12, below.

Table 12	Selenium WoE Evaluation
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is measured at concentrations equivalent to or lower than reference stations.

Silver

An overall screening **SQC value of 0.57 mg/kg** was adopted from Washington (WSDOE) for silver.

Guideline Review

The literature review indicated that SQC values for silver range from a low of 0.57 mg/kg (indicating low potential for adverse effect) to a high of 3.7 mg/kg (concentration above which adverse effects are almost always expected to occur). Distribution of SQC values is visually depicted on Figure 10.

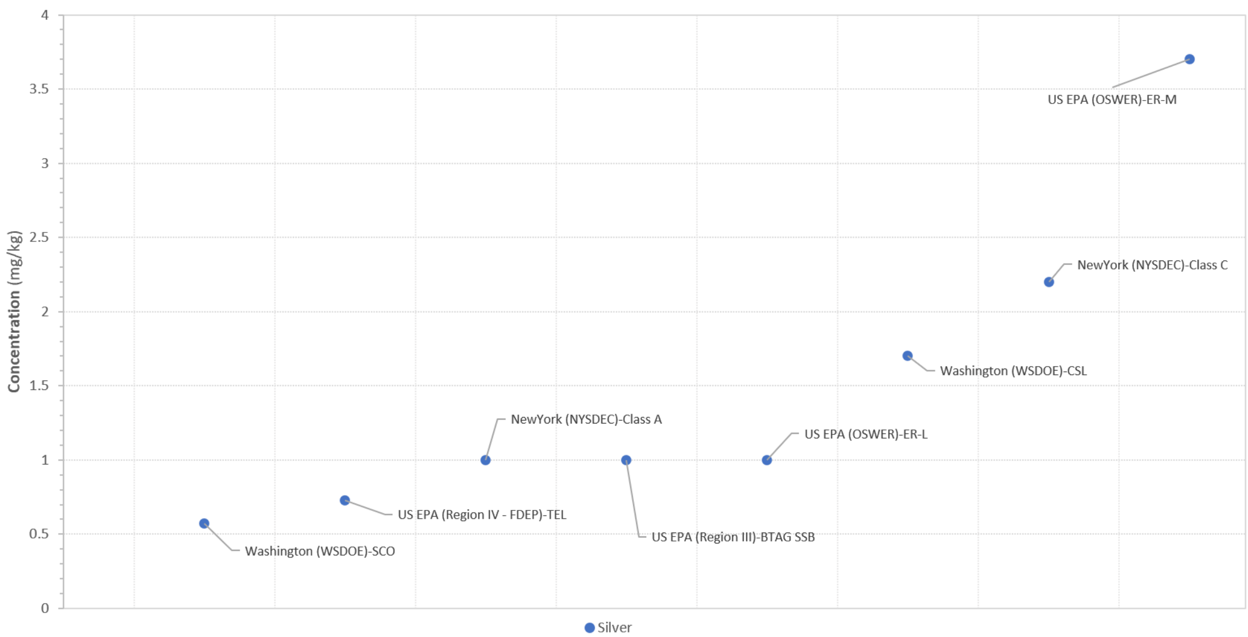

Figure 10. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified within the SETAC-SEDAG database (SEDAG 2016) for silver.

Direct Soil Contact Receptors Check

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration was not identified for humans, but several avian and mammalian screening values were identified; the lowest of which was 4.2 mg/kg for protection of avian (insectivore) receptors. It is understood that these values are reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were intended) but are presented here as a simplified check function in effort to evaluate whether further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would inherently be protective of higher trophic levels.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Silver appears to be bioaccumulated, through the ingestion of food, but is not biomagnified through food webs (Hepp *et al*., 2017). This does not preclude the potential for silver to bioconcentrate within select media. The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.9 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

Summary

Results of the WoE analysis are provided in Table 13, below.

Table 13	**Silver WoE Evaluation**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Thallium

A screening value SQC_{low} 0.86 mg/kg was identified from Health Canada (2020). Based on the single study, and single study species from which this guideline was derived, this screening value has low confidence.

Concentrations measured above the SQC_{low} should be evaluated for their potential to elicit adverse effects to aquatic plants as terrestrial plants have been adversely affected at concentrations as low as 1 mg/kg in soil (Health Canada, 2020).

Guideline Review

No SQCs were identified for thallium.

SSTT Derivation

Spiked sediment toxicity values were not identified for thallium within the SETAC SEDAG database (SEDAG 2016). Due to paucity of data with respect to an established SQC value relevant white-literature resources (published resources) and grey-literature (white-papers and unpublished work) were reviewed.

Health Canada conducted a screening level health assessment of thallium and its compounds pursuant to section 68 and 74 of the Canadian Environmental Protection Act, 1999 (CEPA) (Health Canada 2020). The document is currently in draft but provides a comprehensive review of the human and ecological health risks associated with thallium exposure. It also provides a review of the current state of knowledge as it pertains to ecotoxicity of thallium in sediment. In their review it is indicated that information is scarce and insufficient to derive an SQC but does reference the study by Borgmann et al. (1998) which suggests concentrations between 0.11 and 0.86 mg/kg are unlikely to cause adverse environmental effects.

Due to a lack of literature pertaining to sediment toxicity a screening value SQC_{low} 0.86 mg/kg was identified from Health Canada (2020). Based on the single study, and single study species from which this guideline was derived, this screening value has low confidence.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.9 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration was not identified for humans and only a single reference value of 1 mg/kg was identified for ecological receptors protection (protective of livestock). It is known that concentrations as low as 1 mg/kg in soil can lead to adverse effects in both terrestrial invertebrates and plants (Health Canada 2020).

Table 14	**Thallium WoE Evaluation**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Uranium

An screening **SQC value of 0.594 mg/kg** was selected for uranium

Guideline Review

No SQCs were identified for uranium.

SSTT Derivation

Spiked sediment toxicity values used in derivation of the uranium SST benchmark were obtained from the SETAC-SEDAG database (SEDAG 2016). Consistent with CCME (1995) the lowest of LOEC values was multiplied by an Uncertainty Factor (UF) of 0.2. The calculated value of 0.594 mg/kg is close to meeting the minimum requirements for derivation of a freshwater SQC for uranium and therefore confidence in this value is considered moderate.

Spiked Sediment Toxicity Testing Results - Uranium

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Chironomus riparius	larvae	10	survival	LC20	2.49	mg/kg	NA	Unspecified	Dias et al. 2008
Chironomus riparius	larvae	10	survival	NOEC	2.97	mg/kg	NA	Unspecified	Dias et al. 2008
Chironomus riparius	larvae	10	growth	NOEC	2.97	mg/kg	NA	Unspecified	Dias et al. 2008
Chironomus riparius	larvae	10	development	NOEC	2.97	mg/kg	NA	Unspecified	Dias et al. 2008
Chironomus riparius	larvae	10	growth	LOEC	2.97	mg/kg	NA	Unspecified	Dias et al. 2008
Chironomus riparius	larvae	10	survival	LC50	5.3	mg/kg	NA	Unspecified	Dias et al. 2008
Chironomus riparius	larvae	10	survival	LOEC	6.07	mg/kg	NA	Unspecified	Dias et al. 2008
Chironomus riparius	larvae	10	development	LOEC	6.07	mg/kg	NA	Unspecified	Dias et al. 2008
Chironomus dilutus	juvenile	10	growth	NOEC	740	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	NOEC	807	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	LC25	964	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	LC25	1440	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	LC25	1449	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	NOEC	1819	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	LOEC	1819	mg/kg	NA	7.4	Liber et al. 2011

Hyalella azteca	juvenile	10	growth	LC50	1918	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	LC50	2442	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	NOEC	2551	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	LOEC	2551	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	LC50	2695	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	LOEC	4455	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	LC25	4849	mg/kg	NA	7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	LOEC	7471	mg/kg	NA	7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	LC50	10551	mg/kg	NA	7.4	Liber et al. 2011
		Derived guideline (LOEC*UF 0.2)			0.594				

Notes:
NA - not applicable
NOEC - no observed effect concentration
LOEC - lowest observed effect concentration
LC_{25} - 25% reduction in survival to uranium
LC_{50} - 50% reduction in survival to uranium

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Uranium is unlikely to biomagnify in aquatic ecosystems (Bergman and Graça, 2020). A sediment-to-benthic invertebrate bioconcentration factor was not reported by the US EPA (1999).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 23 mg/kg for humans and 33 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were intended). They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would inherently be protective of higher these higher trophic organisms as well.

Summary

Results of the WoE analysis are provided in Table 15.

Table 15	**Uranium WoE Evaluation**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Vanadium

An overall screening **SQC value of 125 mg/kg** was selected for vanadium, but concentrations exceeding **7.8 mg/kg** (or at levels statistical dissimilar from background) should be evaluated for their potential risk to wildlife ingesting benthic invertebrates (US EPA 2005).

Guideline Review

No SQCs were identified for vanadium.

SSTT Derivation

Spiked sediment toxicity values were not identified within the SETAC-SEDAG database (SEDAG 2016) for vanadium. The review was expanded to include other relevant white-literature resources (published resources) and the grey-literature (white-papers and unpublished work).

Few studies were identified in the literature and only one spiked-sediment assessment was identified. The spiked sediment study was completed as part of a masters thesis in which juvenile *Hyalella azteca* were exposed to vanadium in both spiked natural sediment and field-contaminated source sediment from Lake Catherine (Arkansas, USA) (Bennett 2016). Effects on survival and growth were assessed following 28-day exposures with LC_{10} and LC_{50} values of 417 and 742 mg/kg, respectively.

Effects on the relative growth rate were observed only at the measured concentration of 626 mg/kg (LOEC) but not at 1,269 mg/kg in the field contaminated sediment. Absence of effect in field-contaminated sediment may be indicative that bioavailability is lower in field sediments and thus toxicity may have been overestimated in spiked sediment trials. An acute toxicity test conducted by Nedrich *et al.* (2018) in which juvenile *Hyalella azteca* were exposed to two field collected sediments with vanadium concentrations of 807 and 1,125 mg/kg. However, no statistically significant effect on survival or growth was noted in comparison to the control sediment (31.24 mg/kg) nor the reference-site sediment (118.16 mg/kg).

Using a value of 625 mg/kg as the LOEC and applying UF of 0.2 (consistent with CCME 1995) results in a screening SQC value of 125 mg/kg. The derived SQC could be overly conservative provided both Bennett (2016) and Nedrich *et al.* (2018) reported a no observed effects concentration (NOEC) in field collected sediments of 1,269 mg/kg and 1,125 mg/kg, respectively.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Vanadium is unlikely to biomagnify in aquatic ecosystems (Jardine *et al.*, 2019). The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is XX (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration was not identified for humans and value of 7.8 mg/kg was identified for wildlife receptors. It should be noted that this value is reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were intended). Natural vanadium concentrations in sediment often exceed this value by an order of magnitude or more (US Department of Health and Human Services Agency for Toxic Substances and Disease Registry (ATSDR) 2012).

Summary

Results of the WoE analysis are provided in Table 16, below.

Table 16	**Vanadium WoE Evaluation**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.

Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

* if vanadium contamination is expected an assessment of the potential for risk to waterfowl is recommended (see US EPA EcoSSL for vanadium 2005).

Zinc

An overall screening **SQC value of 7.4 mg/kg** was derived for Zinc.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 80 mg/kg (REL) (indicating low potential for adverse effect) to 4,200 mg/kg (CSL) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 11.

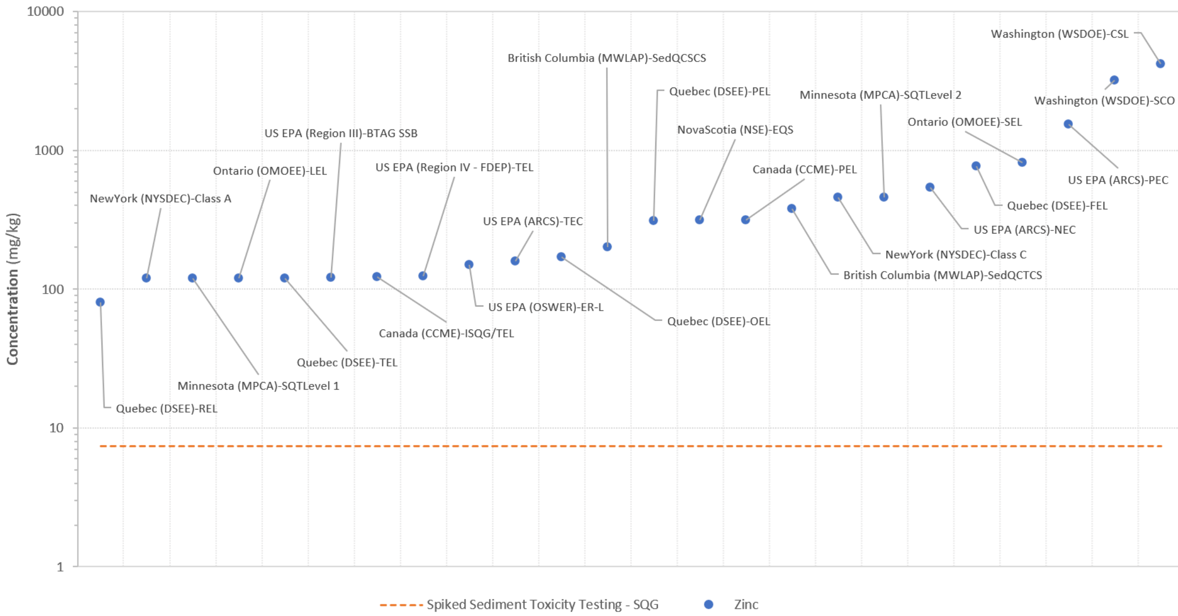

Figure 11. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots). The orange dashed line indicates a calculated SST benchmak value based on the CCME SST approach (7.36 mg/kg).*

SSTT Derivation

Spiked sediment toxicity values used in derivation of the zinc SST benchmark were obtained from the SETAC-SEDAG database (SEDAG 2016). Consistent with CCME (1995) the lowest of the LOEC values was multiplied by a UF of 0.2. The calculated value of 7.36 mg/kg is lower than any of the SQC values reviewed. This may reflect the difficulties associated with the NSTP approach as these values are not based on a dose-response relationship. The SST benchmark meets minimum data-set requirements for derivation of a freshwater SQC for zinc and therefore confidence in this value is considered high.

Spiked Sediment Toxicity Testing Results - Zinc

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Quinquelaophonte sp	adult	14	reproduction	EC10	29.3	mg/kg	NA	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	14	reproduction	LOEC	36.8	mg/kg	NA	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	14	reproduction	EC20	36.9	mg/kg	NA	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	14	reproduction	EC50	54.5	mg/kg	NA	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	14	survival	LC10	97.7	mg/kg	NA	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	14	survival	LC20	108	mg/kg	NA	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	14	survival	LC50	128	mg/kg	NA	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	4	survival	LC10	140	mg/kg	NA	1.03	Stringer et al. 2014
Rhepoxynius abronius	adult	10	survival	LC10	158	mg/kg	NA	0.25	Swartz et al. 1988
Quinquelaophonte sp	adult	4	survival	LC20	159	mg/kg	NA	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	4	survival	LC50	196	mg/kg	NA	1.03	Stringer et al. 2014
Rhepoxynius abronius	adult	10	survival	LC50	270	mg/kg	NA	0.25	Swartz et al. 1988
Rhepoxynius abronius	adult	10	survival	LC50	276	mg/kg	NA	0.25	Swartz et al. 1988
Melita plumulosa	juvenile	42	fertility	EC50	630	mg/kg	NA	Unspecified	Gale et al. 2006
Amphiascus tenuiremis	adult	4	survival	LC50	671.3	mg/kg	NA	2.77	Hagopian-Schlekat et al. 2001
Melita plumulosa	juvenile	42	fertility	EC50	1120	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	survival	LC50	1520	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	bioaccumulation	LOEC	1530	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	bioaccumulation	LOEC	1770	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	growth	EC20	1770	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	gravidity	EC50	1770	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	42	survival	LC50	1770	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	10	survival	LC50	1790	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	juvenile	10	survival	NOEC	2290	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	adult	10	survival	NOEC	2290	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	juvenile	10	survival	LOEC	2290	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	juvenile	10	survival	EC50	3420	mg/kg	NA	Unspecified	Gale et al. 2006
Melita plumulosa	juvenile	10	growth	EC20	3650	mg/kg	NA	Unspecified	Gale et al. 2006
Tellina deltoidalis	adult	10	survival	NOEC	4000	mg/kg	NA	4.5	King et al. 2010
Melita plumulosa	adult	10	survival	LOEC	4530	mg/kg	NA	14	King et al. 2006b
Melita plumulosa	adult	10	survival	LC50	9040	mg/kg	NA	14	King et al. 2006b
		Derived guideline (LOEC*UF 0.2)			7.36				

Notes:

NA - not applicable

NOEC - no observed effect concentration

LOEC - lowest observed effect concentration
EC_{10} - 10% reduction in the endpoint (e.g. growth
EC_{20}- 20% reduction in the endpoint (e.g. growth
LC_{10} - 10% reduction in survival to zinc
LC_{20} - 20% reduction in survival to zinc
LC_{50} - 50% reduction in survival to zinc

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Zinc does not generally biomagnify in aquatic ecosystems but biomagnification is possible in circumstances where dietary zinc concentrations are below those required for metabolism (Cardwell *et al.* 2013). The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.57(mg COPC / kg wet tissue per mg COPC / kg dry sediment).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 10,000 mg/kg for humans and 46 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were intended). They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms.

Summary

Results of the WoE analysis are provided in Table 15, below.

Table 17	Zinc WoE Evaluation
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

The following biomagnification check applies to Low Molecular Weight PAHs discussed below.

There were no biomagnification-based sediment quality guidelines identified. Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012). There were no sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) for low MW PAHs.

Acenaphthene

An overall screening **SQC value of 0.0037 mg/kg** was adopted from Quebec (DSEE) LEL for acenaphthene.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.0037 mg/kg (REL) (indicating low potential for adverse effect) to a high of 470 mg/kg (EqP derived conventional chronic aqueous benchmark protective of Daphnids (invertebrates)). Distribution of the SQC values is visually depicted on Figure 12.

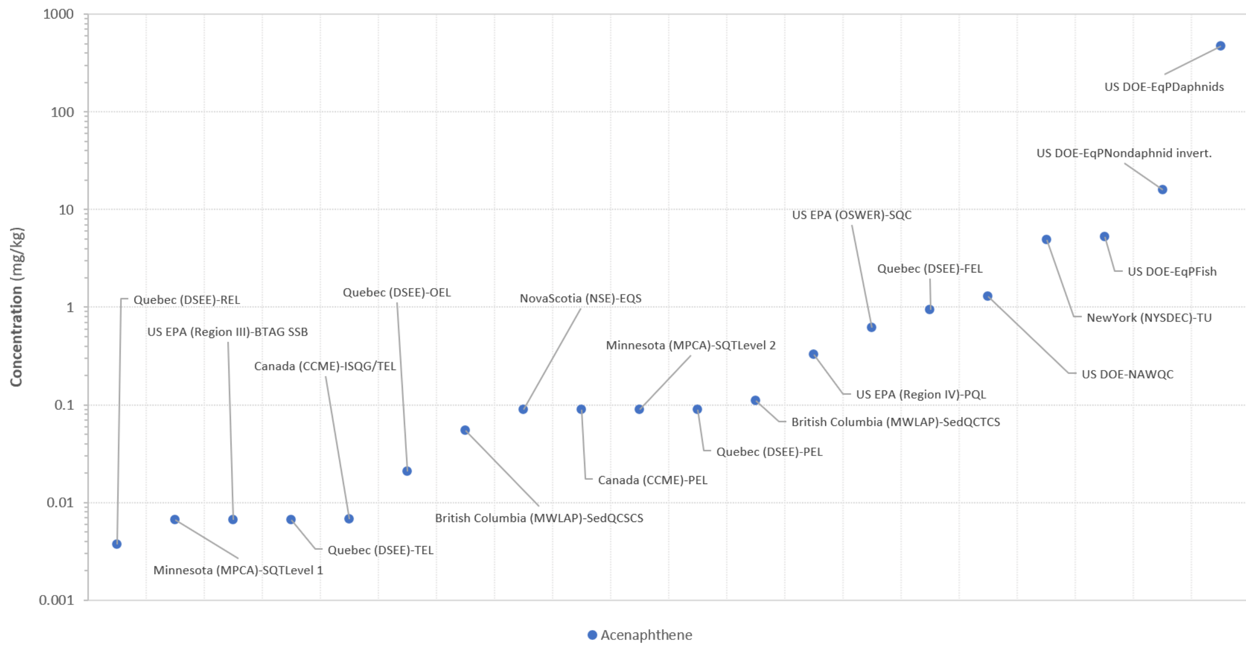

Figure 12. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were available from the SETAC-SEDAG database (SEDAG 2016) but did not support the derivation of an SST benchmark.

Spiked Sediment Toxicity Testing Results - Acenapthene

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Rhepoxynius abronius	Undefined	10	survival	LC50	63.3	mg/kg	2110	3	Swartz et al. 1990
Rhepoxynius abronius	Undefined	10	survival	LC50	69.3	mg/kg	2310	3	Swartz et al. 1990

Notes:
LC_{50} - 50% reduction in survival to acenapthene

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 5,300 mg/kg for humans and 21.5 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were intended). They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments.

Summary

Results of the WoE analysis are provided in Table 16, below.

Table 18	**SQC - Acenaphthene**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Acenaphthylene

An overall screening **SQC value of 0.0033 mg/kg** was adopted from Quebec (DREE) LEL for acenaphthylene.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.0033 mg/kg (REL) (indicating low potential for adverse effect) to a high of 4.52 mg/kg (narcosis and EqP partitioning model indicating concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 13.

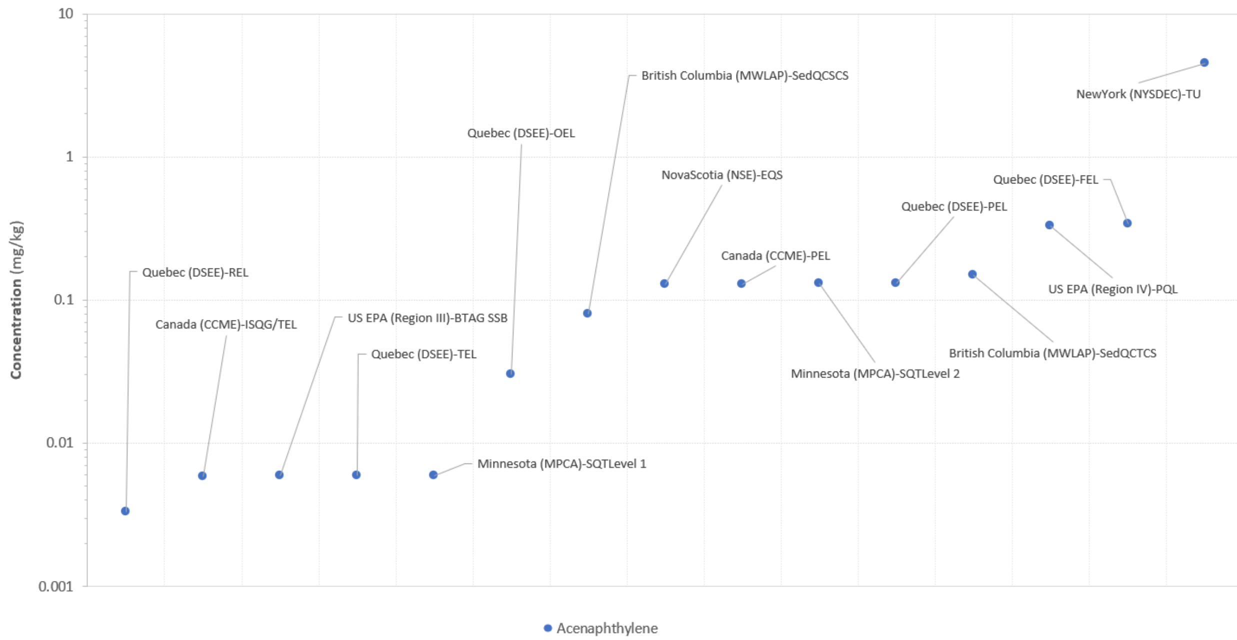

Figure 13. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified for acenaphthylene.

Summary

Results of the WoE analysis are provided in Table 19, below.

Table 19	SQC - Acenaphthylene
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Anthracene

An overall screening **SQC value of 0.0087 mg/kg** was adopted from the US EPA for anthracene.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.0087 mg/kg (REL) (indicating low potential for adverse effect) to 15 mg/L (SEL) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 14.

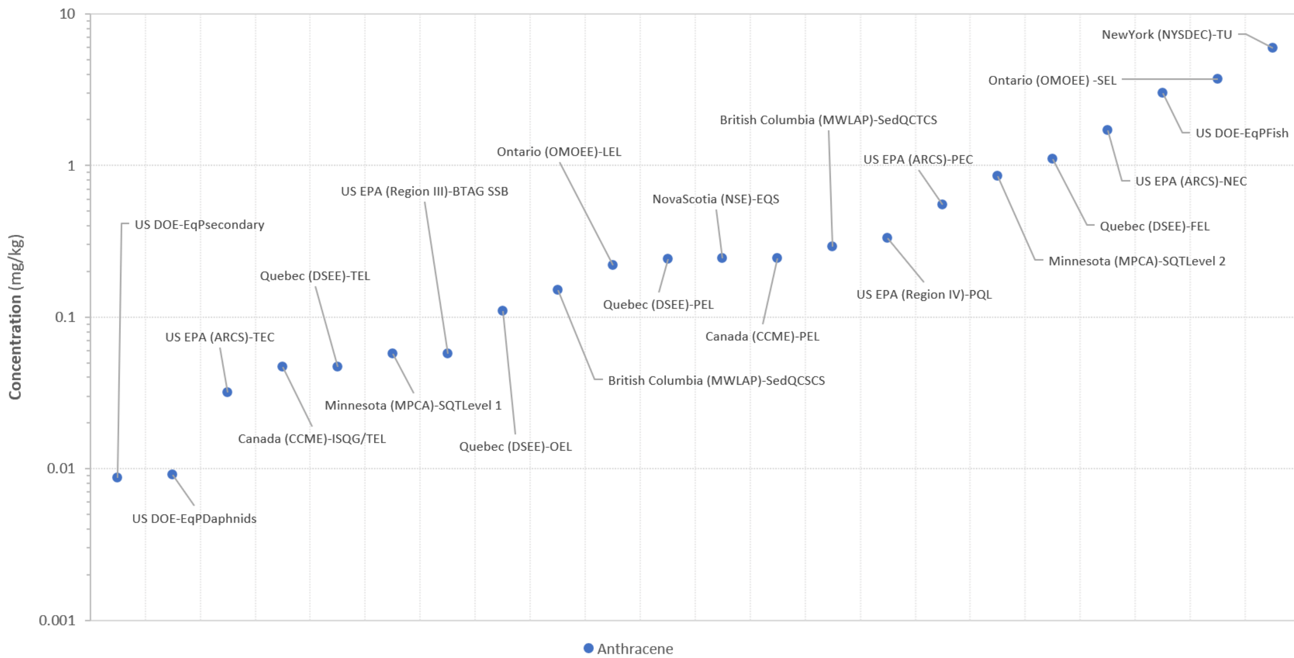

Figure 14. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were available from the SETAC-SEDAG database (SEDAG 2016) but did not support the derivation of an SST benchmark.

Spiked Sediment Toxicity Testing Results - Anthrancene									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Hyalella azteca	juvenile	10	survival	LC50	3.332	mg/kg	850	0.39	Hatch and Burton Jr 1999

Notes:
LC_{50} - 50% reduction in survival to anthracene

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 24,000 mg/kg for humans and 61.5 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments.

Summary

Results of the WoE analysis are provided in Table 20, below.

Table 20	**SQC - Anthracene**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Benz[a]anthracene

An overall screening **SQC value of 0.0079 mg/kg** was derived for benz[a]anthracene considering carcinogenicity and bioaccumulation potential. This is a human health protection criteria for consumption of fish tissues.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.014 mg/kg (REL) (indicating low potential for adverse effect) to a high of 15 mg/kg (SEL) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 15. None of the identified guidelines considered bioaccumulation in food webs or carcinogenicity.

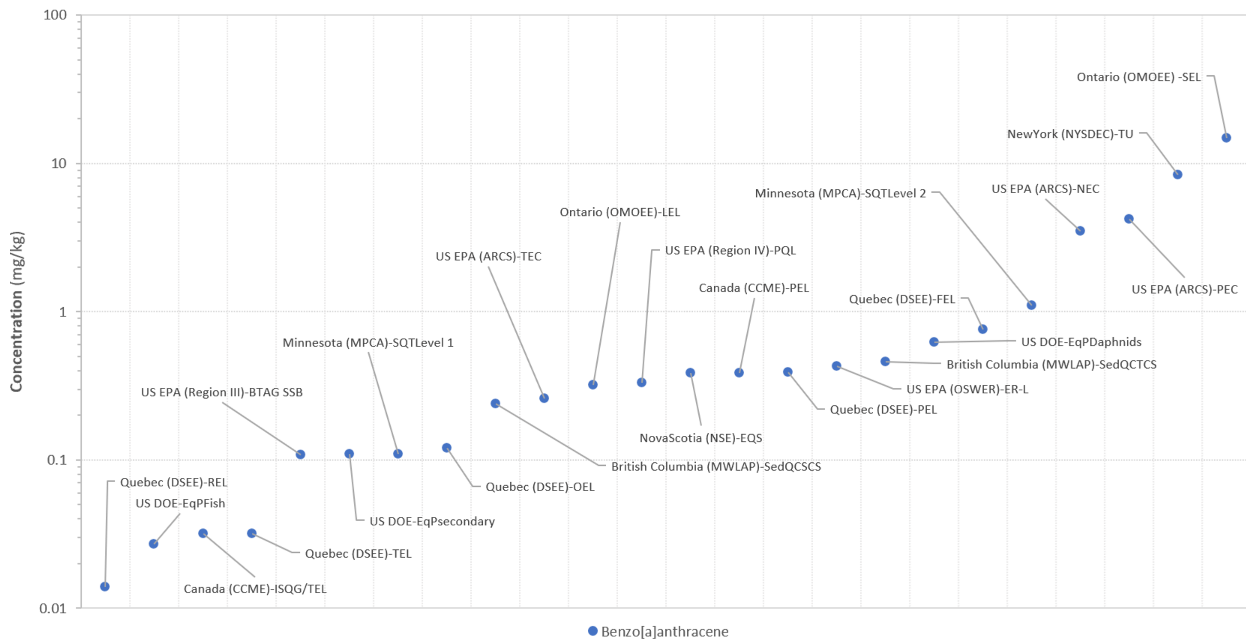

Figure 15. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified for benz[a]anthracene.

Biomagnification Check

The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 1.45 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. Human direct contact guideline for carcinogenic PAHs is based on benzo[a]pyrene (B[a]P) Total Potency Equivalence (TPE). TPE values are calculated by multiplying the soil concentration of individual carcinogenic PAHs by a B[a]P Potency Equivalency Factor (PEF) to produce the B[a]P relative potency concentration and by subsequently summing the relative potency concentrations for the entire PAH mixture (AEP 2019). The direct contact screening value for the summation of the relative potency concentrations in soil is 5.3 mg/kg. Concentrations in sediment at or above this value should undergo site-specific risk assessment to address potential for human health concerns. A screening value of 6.2 mg/kg was identified for wildlife. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments as the screening values identified for terrestrial receptor exposures is nearing the upper end of the identified SQC values from literature.

The potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012). Regardless of this fact, the K_{ow} of select PAH parameters meets the technical requirements under CEPA (1999) for consideration as bioaccumulating. Benz[a]anthracene has a $\log K_{ow}$ of 5.81 and thus the decision was made to derive a screening sediment quality guideline for the protection of human health. The process is described herein.

Establish the Risk Specific Dose (RsD):

The risk specific dose (RsD) was based on the oral slope factor (SF) established for Benzo[a]Pyrene (B[a]P) and the standardized potency equivalence factor (PEF) for benz[a]anthracene of 0.1 (CCME 2016, AEP 2019). This is a slight departure from calculating a human exposure dose estimate from measured fish tissue concentrations and ultimately summing the resultant ILCR values of the carcinogenic PAHs. The method described herein is equivalent but has several advantages over the direct application of an oral slope factor and calculation of a human exposure dose, these include:

- The RsD is provided in units of mg/kg-day and can thus be used to establish a fish-tissue concentration (mg/kg) protective of human health.
- The use of a slope factor results in a number that cannot be easily compared in the same method as non-carcinogenic or threshold chemicals (*i.e.,* comparison of the exposure value to the slope factor results in the reader having to compare the quotient value to the acceptable risk level of 10^{-5} instead of 1), the process as described normalizes the evaluation across all chemicals regardless of their effect endpoint.

- The PEF is typically multiplied by the exposure concentration (measured concentration of the PAH in the media). This requires the end-user to revise their measured concentration every time they conduct a carcinogenic risk-assessment for PAHs. Instead, by dividing the RsD by this same PAH specific value the resultant guideline can be compared directly to the measured concentration within the media of concern.

$$RsD = \frac{ARL}{SF_{B[a]P}} \Big/ PEF$$

$$RsD = \frac{10^{-5}}{2.3} \Big/ 0.1$$

$$RsD = 4.35 \times 10^{-5}\ mg/kg - day$$

Where:

RsD	=	Risk Specific Dose (for carcinogenic chemicals)
ARL	=	Acceptable Risk Level (1 in 100,000)
SF	=	Slope Factor
PEF	=	Potency Equivalence Factor

Establish ADI in Fish Tissue:

Based on the relative potency RsD the acceptable daily intake (ADI) within fish tissue can be calculated as follows:

$$ADI = \frac{RsD \times BW}{Fish\ Consumption\ Rate}$$

$$ADI = \frac{4.35 \times 10^{-5} \times 70.7}{0.00794}$$

$$ADI = 0.387\ mg/kg$$

Where:

ADI	=	Acceptable Daily Intake (mg/kg)
RsD	=	Risk Specific Dose (mg/kg-day)
BW	=	For carcinogens an adult body weight is used (70.7 kg)
FCR	=	Fish Consumption Rate (based on FNFNES 2013) (kg/day)

Determine Baseline BAF from K_{ow}:

$$BAF_{Baseline} = K_{ow} \times FCM$$

$$BAF_{Baseline} = 645{,}654 \times 10.58$$

$$BAF_{Baseline} = 6.83 \times 10^{6}$$

Where:

BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 5.81)
FCM	=	Food Chain Multiplier (10.58 based on Trophic Level of 3.5)

Determine Freely Dissolved Fraction of Chemical in Water:

$$f_{fd} = \frac{1}{1 + \frac{(DOC)(K_{ow})}{10} + (POC)(K_{ow})}$$

$$f_{fd} = \frac{1}{1 + \frac{(0.000002)(645{,}654)}{10} + (0)(645{,}654)}$$

$$f_{fd} = 0.8856$$

Where:

ffd	=	freely dissolved fraction of a chemical in water
DOC	=	concentration of dissolved organic carbon in water (kg DOC/L)
POC	=	concentration of particulate organic carbon in water (kg POC/L)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 5.81)

Determine the Wildlife BAF from Baseline BAF:

$$BAF_{Trophic\ Level_{3.5}}^{Receptor} = \left[(BAF_{Baseline}) \times \left(\%Lipid_{Trophic\ Level_{3.5}\ Fish}\right) + 1\right]\left(f_{fd}\right)$$

$$BAF_{Trophic\ Level_{3.5}}^{Receptor} = [(6.83 \times 10^{6}) \times (0.0835) + 1](0.8856)$$

$$BAF_{Trophic\ Level_{3.5}}^{Receptor} = 507{,}514$$

Where:

$BAF_{Trophic\ Level_{3.5}}^{Receptor}$	=	BAF for consumption of fish from a trophic level of 3.5 (Zanden et al., 1996)
BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific) (L/kg)
%Lipidtrophic level	=	%lipid in fish for a given trophic level (8.35%)
ffd	=	freely dissolved fraction of a chemical in water

Determine the BAF-Based Water Quality Value for Porewater:

$$C_{pw} = \frac{ADI}{BAF_{Trophic\ Level_{3.5}}^{Receptor} \times \%\ of\ Diet}$$

$$C_{pw} = \frac{0.387}{507{,}514 \times 100\%}$$

$$C_{pw} = 7.63 \times 10^{-7}\ mg/L\ \ or\ 7.63 \times 10^{-4}\ \mu g/L$$

Where:

ADI	=	Acceptable Daily Intake in Fish (mg/kg)
$BAF_{Trophic\ Level_{3.5}}^{Receptor}$	=	BAF for consumption of fish from a trophic level of 3.5 (Zanden et al., 1996) (L/kg)
%Diet	=	Assume 100% of diet is fish from a trophic level of 3.5
Cpw	=	Concentration in Porewater (mg/L)

Calculate the Sediment Guideline for Protection of Fish Tissue Tainting via Equilibrium Partitioning Method:

$$SQC_{OC} = C_{pw} \times K_{oc} \times \frac{1kg}{1{,}000gOC}$$

$$SQC_{OC} = 7.63 \times 10^{-4} \times 514{,}648 \times 0.001$$

$$SQC_{OC} = 0.393\ \mu g/gOC$$

Where:

Cpw	=	Concentration in Porewater (µg/L)
Koc	=	Soil Adsorption Coefficient (gOC/g soil)
SQCoc	=	Sediment Quality Guideline (µg/gOC)

Define a Final Sediment Quality Guideline for an Assumed TOC in Sediment of 2%:

$$SQC = SQC_{OC} \times TOC$$

$$SQC = 0.393 \times 20$$

$$SQC = 7.85\ \mu g/kg\ \ or\ 0.0079\ mg/kg$$

Where:

SQCoc	=	Sediment Quality Criteria normalized to OC
SQC	=	Sediment Quality Criteria (µg/kg)
%TOC	=	Percent Total Organic Carbon (expressed as g•OC/kg)

Summary

Results of the WoE analysis are provided in Table 21, below. Consideration of the potential for PAH exposures in fish tissue is required as concentrations lower than the SQC_{low} were identified via partitioning theory (0.0079 mg/kg). Therefore, during any investigation regarding contamination in sediment due to PAHs the potential for carcinogenic risk relating to fish consumption should also be evaluated.

Table 21	**Benzo[a]anthracene WoE Approach**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** 0.0079 mg/kg

Benzo[a]pyrene

An overall screening **SQC value of 0.000616 mg/kg** was derived for benzo[a]pyrene considering carcinogenicity and bioaccumulation potential. This is a human health protection criteria for consumption of fish tissues.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.0319 mg/kg (ISQC/TEL) (indicating low potential for adverse effect) to a high of 14.4 mg/kg (SEL) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 16. None of the identified guidelines considered bioaccumulation in food webs or carcinogenicity.

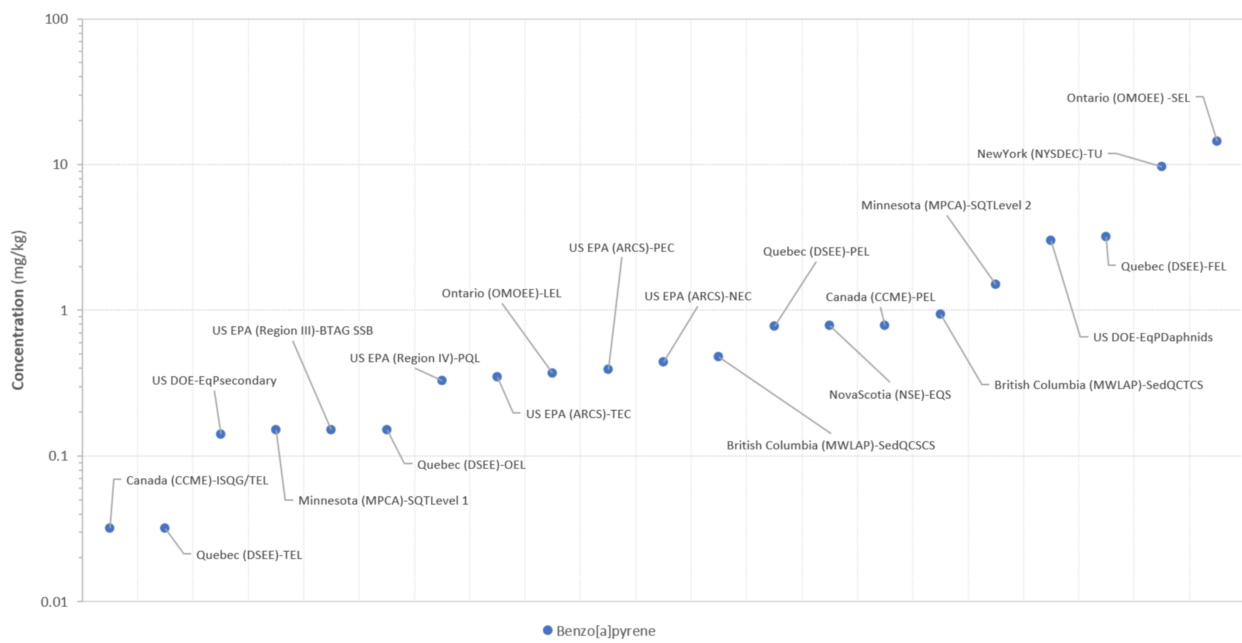

Figure 16. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were available from the SETAC-SEDAG database (SEDAG 2016) but bioaccumulation potential was identified and methods to address carcinogenicity and bioaccumulation potential were required as described below.

Spiked Sediment Toxicity Testing Results - Benzo[a]pyrene

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (µg/g-OC)	TOC (%)	Citation
Chironomus dilutus	larvae	43	reproduction	EC5	0.03488	mg/kg	2.18	1.6	Du et al. 2014
Chironomus dilutus	larvae	43	emergence	EC5	0.05456	mg/kg	3.41	1.6	Du et al. 2014
Chironomus dilutus	larvae	43	growth	EC5	0.10608	mg/kg	6.63	1.6	Du et al. 2014
Chironomus dilutus	larvae	43	reproduction	EC50	0.2144	mg/kg	13.4	1.6	Du et al. 2014
Chironomus dilutus	larvae	43	emergence	EC50	0.4304	mg/kg	26.9	1.6	Du et al. 2014
Chironomus dilutus	larvae	43	growth	EC50	0.6576	mg/kg	41.1	1.6	Du et al. 2014
Chironomus dilutus	larvae	43	survival	LC50	0.9104	mg/kg	56.9	1.6	Du et al. 2014
Chironomus dilutus	larvae	43	survival	LC50	1.48	mg/kg	92.5	1.6	Du et al. 2014

Notes:

EC_5 - 5% reduction in the endpoint

EC_{50}- 50% reduction in the endpoint

LC_{50} - 50% reduction in survival to Benzo[a]pyrene

Biomagnification Check

Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 1.59 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012). Regardless of this fact, the K_{ow} of select PAH parameters does meet the technical requirements under CEPA (1999) for consideration as bioaccumulating.

Benzo[a]pyrene has a $\log K_{ow}$ of 6.13 and thus the decision was made to derive a screening sediment quality guideline for the protection of human health. This is further supported by the fact that the NYSDEC (2014) has published BSGVs (TOC 2%) for human health (fish consumption) ranging from 0.0045 mg/kg (saltwater sediment) to 0.018 mg/kg (freshwater sediment).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. Human direct contact guideline for carcinogenic PAHs is based on B[a]P TPE. TPE values are calculated by multiplying the soil concentration of individual carcinogenic PAHs by a PEF to produce the B[a]P relative potency concentration and by subsequently summing the relative potency concentrations for the entire PAH mixture (AEP 2019). The direct contact screening value for the summation of the relative potency concentrations in soil is 5.3 mg/kg. Concentrations in sediment at or above this value should undergo site-specific risk assessment to address potential for human health concerns. A screening value of 0.6 mg/kg was identified for wildlife. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms, but heavily impacted sediments should include consideration that adverse effects may occur in higher trophic level wildlife receptors.

Establish the Risk Specific Dose (RsD):

The risk specific dose (RsD) was based on the oral slope factor (SF) established for Benzo[a]Pyrene. This is a slight departure from calculating a human exposure dose estimate from measured fish tissue concentrations and ultimately summing the resultant ILCR values of the carcinogenic PAHs. The method described herein is equivalent but has several advantages over the direct application of an oral slope factor and calculation of a human exposure dose, these include:

- The RsD is provided in units of mg/kg-day and can thus be used to establish a fish-tissue concentration (mg/kg) protective of human health.
- The use of a slope factor results in a number that cannot be easily compared in the same method as non-carcinogenic or threshold chemicals (i.e., comparison of the exposure value to the slope factor results in the reader having to compare the quotient value to the acceptable risk level of 10-5 instead of 1), the process as described normalizes the evaluation across all chemicals regardless of their effect endpoint.

$$RsD = \frac{ARL}{SF_{B[a]P}}$$

$$RsD = \frac{10^{-5}}{2.3}$$

$$RsD = 4.35 \times 10^{-6}\ mg/kg - day$$

Where:

RsD	=	Risk Specific Dose (for carcinogenic chemicals)
ARL	=	Acceptable Risk Level (1 in 100,000)
SF	=	Slope Factor
PEF	=	Potency Equivalence Factor

Establish ADI in Fish Tissue:

Based on the relative potency RsD the acceptable daily intake (ADI) within fish tissue can be calculated as follows:

$$ADI = \frac{RsD \times BW}{Fish\ Consumption\ Rate}$$

$$ADI = \frac{4.35 \times 10^{-6} \ \times 70.7}{0.00794}$$

$$ADI = 0.0387\ mg/kg$$

Where:

ADI	=	Acceptable Daily Intake (mg/kg)
RsD	=	Risk Specific Dose (mg/kg-day)
BW	=	For carcinogens an adult body weight is used (70.7 kg)
FCR	=	Fish Consumption Rate (based on FNFNES 2013) (kg/day)

Determine Baseline BAF from K_{ow}:

$$BAF_{Baseline} = K_{ow} \times FCM$$

$$BAF_{Baseline} = 1{,}348{,}963 \times 14.99$$

$$BAF_{Baseline} = 2.02 \times 10^{7}$$

Where:

BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 6.13)
FCM	=	Food Chain Multiplier (14.99 based on Trophic Level of 3.5)

Determine Freely Dissolved Fraction of Chemical in Water:

$$f_{fd} = \frac{1}{1 + \frac{(DOC)(K_{ow})}{10} + (POC)(K_{ow})}$$

$$f_{fd} = \frac{1}{1 + \frac{(0.000002)(1,348,963)}{10} + (0)(1,348,963)}$$

$$f_{fd} = 0.7875$$

Where:

ffd	=	freely dissolved fraction of a chemical in water
DOC	=	concentration of dissolved organic carbon in water (kg DOC/L)
POC	=	concentration of particulate organic carbon in water (kg POC/L)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 6.13)

Determine the Wildlife BAF from Baseline BAF:

$$BAF^{Receptor}_{Trophic\ Level_{3.5}} = \left[(BAF_{Baseline}) \times \left(\%Lipid_{Trophic\ Level_{3.5}\ Fish}\right) + 1\right]\left(f_{fd}\right)$$

$$BAF^{Receptor}_{Trophic\ Level_{3.5}} = \left[(2.02 \times 10^{7}) \times (0.0835) + 1\right](0.7875)$$

$$BAF^{Receptor}_{Trophic\ Level_{3.5}} = 1,335,070$$

Where:

$BAF^{Receptor}_{Trophic\ Level_{3.5}}$	=	BAF for consumption of fish from a trophic level of 3.5 (Zanden et al., 1996)
BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific) (L/kg)
%Lipidtrophic level	=	%lipid in fish for a given trophic level (8.35%)
ffd	=	freely dissolved fraction of a chemical in water

Determine the BAF-Based Water Quality Value for Porewater:

$$C_{pw} = \frac{ADI}{BAF_{Trophic\ Level_{3.5}}^{Receptor} \times \%\ of\ Diet}$$

$$C_{pw} = \frac{0.0387}{1,335,070 \times 100\%}$$

$$C_{pw} = 2.90 \times 10^{-8}\ mg/L\ \ or\ 2.90 \times 10^{-5}\ \mu g/L$$

Where:

ADI	=	Acceptable Daily Intake in Fish (mg/kg)
$BAF_{Trophic\ Level_{3.5}}^{Receptor}$	=	BAF for consumption of fish from a trophic level of 3.5 (Zanden et al., 1996) (L/kg)
%Diet	=	Assume 100% of diet is fish from a trophic level of 3.5
Cpw	=	Concentration in Porewater (mg/L)

Calculate the Sediment Guideline for Protection of Fish Tissue Tainting via Equilibrium Partitioning Method:

$$SQC_{OC} = C_{pw} \times K_{oc} \times \frac{1kg}{1,000gOC}$$

$$SQC_{OC} = 2.90 \times 10^{-5} \times 1,061,867 \times 0.001$$

$$SQC_{OC} = 0.0308\ \mu g/gOC$$

Where:

Cpw	=	Concentration in Porewater (μg/L)
Koc	=	Soil Adsorption Coefficient (gOC/g soil)
SQCoc	=	Sediment Quality Guideline (μg/gOC)

Define a Final Sediment Quality Guideline for an Assumed TOC in Sediment of 2%:

$$SQC = SQC_{OC} \times TOC$$

$$SQC_{OC} = \ 0.031\ \times 20$$

$$SQC_{OC} = \ 0.616\, \mu g/kg\ \ or\ 0.000616\, mg/kg$$

Where:

SQCoc	=	Sediment Quality Criteria normalized to OC
SQC	=	Sediment Quality Criteria (µg/kg)
%TOC	=	Percent Total Organic Carbon (expressed as g•OC/kg)

Summary

Results of the WoE analysis are provided in Table 22, below. Consideration of the potential for PAH exposures in fish tissue is required as concentrations lower than the SQC were identified via partitioning theory (0.616 µg/kg). Therefore, during any investigation regarding contamination in sediment due to PAHs the potential for carcinogenic risk relating to fish consumption should also be evaluated.

Table 22	**Benzo[a]pyrene WoE Approach**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** 0.000616 mg/kg

Chrysene

An overall screening **SQC value of 0.079 mg/kg** was derived for chrysene considering carcinogenicity and bioaccumulation potential. This is a human health protection criteria for consumption of fish tissues.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.026 mg/kg (REL) (indicating low potential for adverse effect) to a high of 8.43 mg/kg (narcosis and EqP partitioning model indicating concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 17. None of the identified guidelines considered bioaccumulation in food webs or carcinogenicity.

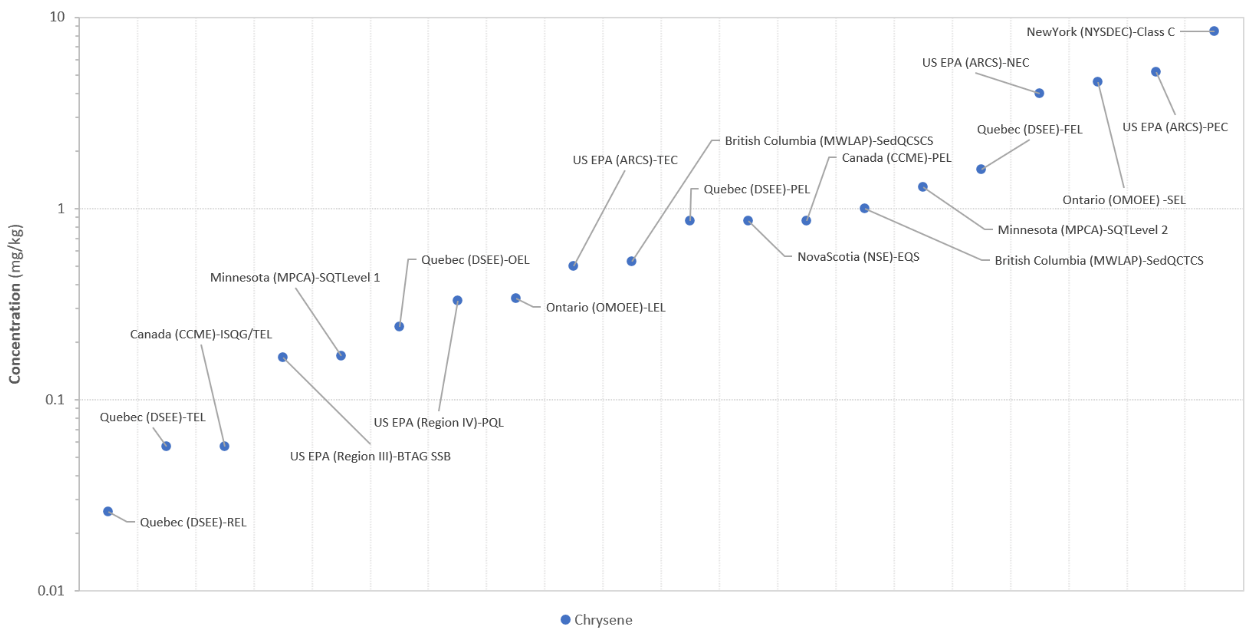

Figure 17. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified for chrysene.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 1.38 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012). Regardless of this fact, the K_{ow} of select PAH parameters does meet the technical requirements under CEPA (1999) for consideration as bioaccumulating. Chrysene has a logK_{ow} of 5.81 and thus the decision was made to derive a screening sediment quality guideline for the protection of human health. The process is described herein.

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. Human direct contact guideline for carcinogenic PAHs is based on B[a]P TPE. TPE values are calculated by multiplying the soil concentration of individual carcinogenic PAHs by a PEF to produce the B[a]P relative potency concentration and by subsequently summing the relative potency concentrations for the entire PAH mixture (AEP 2019). The direct contact screening value for the summation of the relative potency concentrations in soil is 5.3 mg/kg. Concentrations in sediment at or above this value should undergo site-specific risk assessment to address potential for human health concerns. A screening value of 6.2 mg/kg was identified for wildlife. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments.

Establish the Risk Specific Dose (RsD):

The risk specific dose (RsD) was based on the oral slope factor (SF) established for Benzo[a]Pyrene (B[a]P) and the standardized potency equivalence factor (PEF) for chrysene of 0.01 (CCME 2016, AEP 2019). This is a slight departure from calculating a human exposure dose estimate from measured fish tissue concentrations and ultimately summing the resultant ILCR values of the carcinogenic PAHs. The method described herein is equivalent but has several advantages over the direct application of an oral slope factor and calculation of a human exposure dose, these include:

- The RsD is provided in units of mg/kg-day and can thus be used to establish a fish-tissue concentration (mg/kg) protective of human health.
- The use of a slope factor results in a number that cannot be easily compared in the same method as non-carcinogenic or threshold chemicals (*i.e.,* comparison of the exposure value to the slope factor results in the reader having to compare the quotient

value to the acceptable risk level of 10^{-5} instead of 1), the process as described normalizes the evaluation across all chemicals regardless of their effect endpoint.

- The PEF is typically multiplied by the exposure concentration (measured concentration of the PAH in the media). This requires the end-user to revise their measured concentration every time they conduct a carcinogenic risk-assessment for PAHs. Instead, by dividing the RsD by this same PAH specific value the resultant guideline can be compared directly to the measured concentration within the media of concern.

$$RsD = \frac{ARL}{SF_{B[a]P}} \Big/ PEF$$

$$RsD = \frac{10^{-5}}{2.3} \Big/ 0.01$$

$$RsD = 4.35 \times 10^{-4}\ mg/kg - day$$

Where:

RsD	=	Risk Specific Dose (for carcinogenic chemicals)
ARL	=	Acceptable Risk Level (1 in 100,000)
SF	=	Slope Factor
PEF	=	Potency Equivalence Factor

Establish ADI in Fish Tissue:

Based on the relative potency RsD the acceptable daily intake (ADI) within fish tissue can be calculated as follows:

$$ADI = \frac{RsD \times BW}{Fish\ Consumption\ Rate}$$

$$ADI = \frac{4.35 \times 10^{-4} \times 70.7}{0.00794}$$

$$ADI = 3.87\ mg/kg$$

Where:

ADI	=	Acceptable Daily Intake (mg/kg)
RsD	=	Risk Specific Dose (mg/kg-day)
BW	=	For carcinogens an adult body weight is used (70.7 kg)
FCR	=	Fish Consumption Rate (based on FNFNES 2013) (kg/day)

Determine Baseline BAF from K_{ow}:

$$BAF_{Baseline} = K_{ow} \times FCM$$

$$BAF_{Baseline} = 645{,}654 \times 10.58$$

$$BAF_{Baseline} = 6.83 \times 10^{6}$$

Where:

BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 5.81)
FCM	=	Food Chain Multiplier (10.58 based on Trophic Level of 3.5)

Determine Freely Dissolved Fraction of Chemical in Water:

$$f_{fd} = \frac{1}{1 + \frac{(DOC)(K_{ow})}{10} + (POC)(K_{ow})}$$

$$f_{fd} = \frac{1}{1 + \frac{(0.000002)(645{,}654)}{10} + (0)(645{,}654)}$$

$$f_{fd} = 0.8856$$

Where:

ffd	=	freely dissolved fraction of a chemical in water
DOC	=	concentration of dissolved organic carbon in water (kg DOC/L)
POC	=	concentration of particulate organic carbon in water (kg POC/L)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 5.81)

Determine the Wildlife BAF from Baseline BAF:

$$BAF_{Trophic\ Level_{3.5}}^{Receptor} = \left[(BAF_{Baseline}) \times \left(\%Lipid_{Trophic\ Level_{3.5}\ Fish}\right) + 1\right]\left(f_{fd}\right)$$

$$BAF_{Trophic\ Level_{3.5}}^{Receptor} = [(6.83 \times 10^{6}) \times (0.0835) + 1](0.8856)$$

$$BAF_{Trophic\ Level_{3.5}}^{Receptor} = 507{,}514$$

Where:

$BAF_{Trophic\ Level_{3.5}}^{Receptor}$	=	BAF for consumption of fish from a trophic level of 3.5 (Zanden et al., 1996)
BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific) (L/kg)
%Lipidtrophic level	=	%lipid in fish for a given trophic level (8.35%)
ffd	=	freely dissolved fraction of a chemical in water

Determine the BAF-Based Water Quality Value for Porewater:

$$C_{pw} = \frac{ADI}{BAF_{Trophic\ Level_{3.5}}^{Receptor} \times \%\ of\ Diet}$$

$$C_{pw} = \frac{3.87}{507{,}514 \times 100\%}$$

$$C_{pw} = 7.63 \times 10^{-6}\ mg/L\ \ or\ 7.63 \times 10^{-3}\ \mu g/L$$

Where:

ADI	=	Acceptable Daily Intake in Fish (mg/kg)
$BAF^{Receptor}_{Trophic\ Level_{3.5}}$	=	BAF for consumption of fish from a trophic level of 3.5 (Zanden et al., 1996) (L/kg)
%Diet	=	Assume 100% of diet is fish from a trophic level of 3.5
Cpw	=	Concentration in Porewater (mg/L)

Calculate the Sediment Guideline for Protection of Fish Tissue Tainting via Equilibrium Partitioning Method:

$$SQC_{OC} = C_{pw} \times K_{oc} \times \frac{1kg}{1{,}000gOC}$$

$$SQC_{OC} = 7.63 \times 10^{-3} \times 514{,}648 \times 0.001$$

$$SQC_{OC} = 3.93\ \mu g/gOC$$

Where:

Cpw	=	Concentration in Porewater (µg/L)
Koc	=	Soil Adsorption Coefficient (gOC/g soil)
SQCoc	=	Sediment Quality Guideline (µg/gOC)

Define a Final Sediment Quality Guideline for an Assumed TOC in Sediment of 2%:

$$SQC = C \times TOC$$

$$SQC_{OC} = 3.93 \times 20$$

$$SQC_{OC} = 78.5\ \mu g/kg\ \ or\ 0.079\ mg/kg$$

Where:

SQCoc	=	Sediment Quality Criteria normalized to OC
SQC	=	Sediment Quality Criteria (µg/kg)
%TOC	=	Percent Total Organic Carbon (expressed as g•OC/kg)

Summary

Results of the WoE analysis are provided in Table 23, below. Consideration of the potential for PAH exposures in fish tissue is required as concentrations greater than the SQCas identified via partitioning theory (0.079 mg/kg).

A summary table of all chemicals is provided for reference in Appendix D (Table D1).

Table 23	**SQC – Chrysene**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** 0.079 mg/kg

Dibenzo[a,h]anthracene

An overall screening **SQC value of 0.000624 mg/kg** was derived for dibenz[a,h]anthracene considering carcinogenicity and bioaccumulation potential. This is a human health protection criterion for consumption of fish tissues.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.0062 mg/kg (TEL) (indicating low potential for adverse effect) to a high of 11.2 mg/kg (narcosis and EqP partitioning model indicating concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 18. None of the identified guidelines considered carcinogenicity.

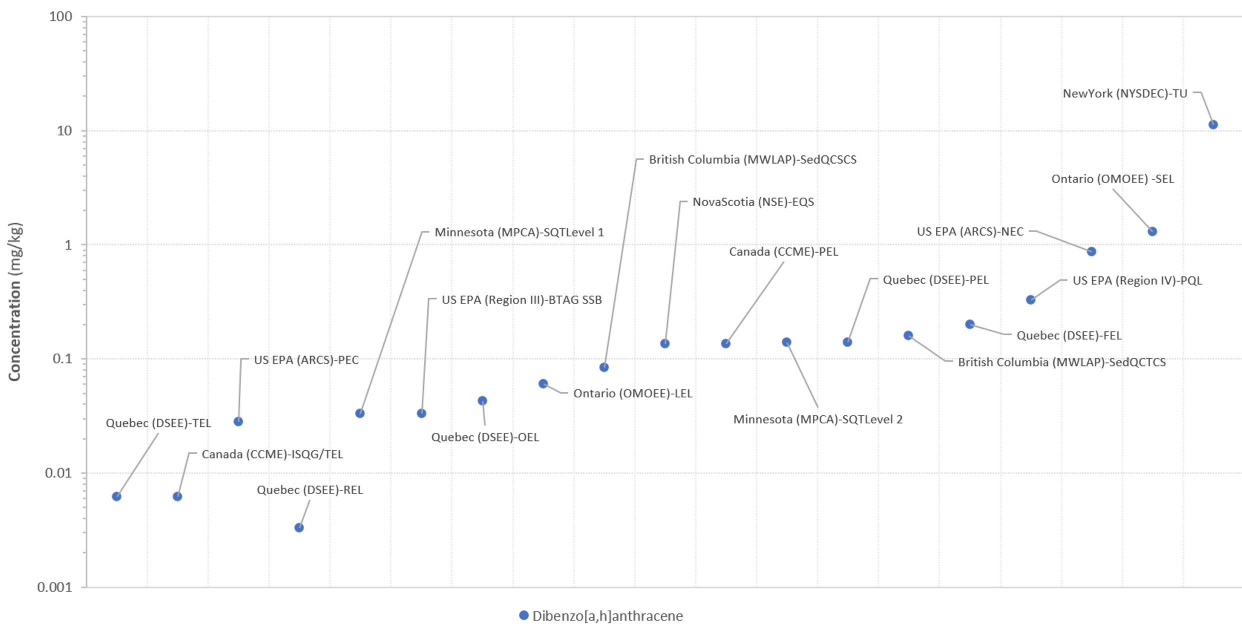

Figure 18. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified for dibenzo[a,h]anthracene.

Biomagnification Check

Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). The sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 1.61 (mg COPC / kg wet tissue per mg COPC / kg dry sediment).

However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012). Regardless of this fact, the K_{ow} of select PAH parameters does meet the technical requirements under CEPA (1999) for consideration as bioaccumulating. Dibzeno[a,h]anthracene has a logK_{ow} of 6.54 and thus the decision was made to derive a screening sediment quality guideline for the protection of human health. The process is described herein and is further supported by the fact that the NYSDEC has published BSGVs (TOC 2%) for human health (fish consumption) of 0.0098 mg/kg for saltwater sediment (NYSDEC 2014).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. Human direct contact guideline for carcinogenic PAHs is based on B[a]P TPE. TPE values are calculated by multiplying the soil concentration of individual carcinogenic PAHs by a PEF to produce the B[a]P relative potency concentration and by subsequently summing the relative potency concentrations for the entire PAH mixture (AEP 2019). The direct contact screening value for the summation of the relative potency concentrations in soil is 5.3 mg/kg. Concentrations in sediment at or above this value should undergo site-specific risk assessment to address potential for human health concerns. A screening value was not identified for wildlife. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments.

Establish the Risk Specific Dose (RsD):

The risk specific dose (RsD) was based on the oral slope factor (SF) established for Benzo[a]Pyrene (B[a]P) and the standardized potency equivalence factor (PEF) for dibenzo[a,h]anthracene of 1 (CCME 2016, AEP 2019). This is a slight departure from calculating a human exposure dose estimate from measured fish tissue concentrations and ultimately summing the resultant ILCR values of the carcinogenic PAHs. The method described herein is equivalent but has several advantages over the direct application of an oral slope factor and calculation of a human exposure dose, these include:

- The RsD is provided in units of mg/kg-day and can thus be used to establish a fish-tissue concentration (mg/kg) protective of human health.
- The use of a slope factor results in a number that cannot be easily compared in the same method as non-carcinogenic or threshold chemicals (*i.e.*, comparison of the exposure value to the slope factor results in the reader having to compare the quotient value to the acceptable risk level of 10^{-5} instead of 1), the process as described normalizes the evaluation across all chemicals regardless of their effect endpoint.

- The PEF is typically multiplied by the exposure concentration (measured concentration of the PAH in the media). This requires the end-user to revise their measured concentration every time they conduct a carcinogenic risk-assessment for PAHs. Instead, by dividing the RsD by this same PAH specific value the resultant guideline can be compared directly to the measured concentration within the media of concern.

$$RsD = \frac{ARL}{SF_{B[a]P}} \Big/ PEF$$

$$RsD = \frac{10^{-5}}{2.3} \Big/ 1$$

$$RsD = 4.35 \times 10^{-6}\ mg/kg - day$$

Where:

RsD	=	Risk Specific Dose (for carcinogenic chemicals)
ARL	=	Acceptable Risk Level (1 in 100,000)
SF	=	Slope Factor
PEF	=	Potency Equivalence Factor

Establish ADI in Fish Tissue:

Based on the relative potency RsD the acceptable daily intake (ADI) within fish tissue can be calculated as follows:

$$ADI = \frac{RsD \times BW}{Fish\ Consumption\ Rate}$$

$$ADI = \frac{4.35 \times 10^{-6}\ \times 70.7}{0.00794}$$

$$ADI = 0.0387\ mg/kg$$

Where:

ADI	=	Acceptable Daily Intake (mg/kg)
RsD	=	Risk Specific Dose (mg/kg-day)
BW	=	For carcinogens an adult body weight is used (70.7 kg)
FCR	=	Fish Consumption Rate (based on FNFNES 2013) (kg/day)

Determine Baseline BAF from K_{ow}:

$$BAF_{Baseline} = K_{ow} \times FCM$$

$$BAF_{Baseline} = 3{,}467{,}369 \times 19.4$$

$$BAF_{Baseline} = 6.73 \times 10^{7}$$

Where:

BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 6.54)
FCM	=	Food Chain Multiplier (19.4 based on Trophic Level of 3.5)

Determine Freely Dissolved Fraction of Chemical in Water:

$$f_{fd} = \frac{1}{1 + \frac{(DOC)(K_{ow})}{10} + (POC)(K_{ow})}$$

$$f_{fd} = \frac{1}{1 + \frac{(0.000002)(3{,}467{,}369)}{10} + (0)(3{,}467{,}369)}$$

$$f_{fd} = 0.5905$$

Where:

ffd	=	freely dissolved fraction of a chemical in water
DOC	=	concentration of dissolved organic carbon in water (kg DOC/L)
POC	=	concentration of particulate organic carbon in water (kg POC/L)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 6.54)

Determine the Wildlife BAF from Baseline BAF:

$$BAF^{Receptor}_{Trophic\ Level_{3.5}} = \left[(BAF_{Baseline}) \times \left(\%Lipid_{Trophic\ Level_{3.5}\ Fish}\right) + 1\right]\left(f_{fd}\right)$$

$$BAF^{Receptor}_{Trophic\ Level_{3.5}} = [(6.73 \times 10^{7}) \times (0.0835) + 1](0.5905)$$

$$BAF^{Receptor}_{Trophic\ Level_{3.5}} = 3{,}331{,}454$$

Where:

$BAF^{Receptor}_{Trophic\ Level_{3.5}}$ (Zanden et al., 1996)	=	BAF for consumption of fish from a trophic level of 3.5
BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific) (L/kg)
%Lipidtrophic level	=	%lipid in fish for a given trophic level (8.35%)
ffd	=	freely dissolved fraction of a chemical in water

Determine the BAF-Based Water Quality Value for Porewater:

$$C_{pw} = \frac{ADI}{BAF^{Receptor}_{Trophic\ Level_{3.5}} \times \%\ of\ Diet}$$

$$C_{pw} = \frac{0.0387}{3{,}331{,}454 \times 100\%}$$

$$C_{pw} = 1.16 \times 10^{-8}\ mg/L\ \ or\ 1.16 \times 10^{-5}\ \mu g/L$$

Where:

ADI	=	Acceptable Daily Intake in Fish (mg/kg)

$BAF^{Receptor}_{Trophic\ Level_{3.5}}$ (Zanden et al., 1996) (L/kg)	=	BAF for consumption of fish from a trophic level of 3.5
%Diet	=	Assume 100% of diet is fish from a trophic level of 3.5
Cpw	=	Concentration in Porewater (mg/L)

Calculate the Sediment Guideline for Protection of Fish Tissue Tainting via Equilibrium Partitioning Method:

$$SQC_{OC} = C_{pw} \times K_{oc} \times \frac{1kg}{1{,}000gOC}$$

$$SQC_{OC} = 1.16 \times 10^{-5} \times 2{,}685{,}963 \times 0.001$$

$$SQC_{OC} = 0.0312\ \mu g/gOC$$

Where:

Cpw	=	Concentration in Porewater (μg/L)
Koc	=	Soil Adsorption Coefficient (gOC/g soil)
SQCoc	=	Sediment Quality Guideline (μg/gOC)

Define a Final Sediment Quality Guideline for an Assumed TOC in Sediment of 2%:

$$SQC = SQC_{OC} \times TOC$$

$$SQC_{OC} = 0.0312 \times 20$$

$$SQC_{OC} = 0.624\ \mu g/kg\ \ or\ 0.000624\ mg/kg$$

Where:

SQCoc	=	Sediment Quality C^riteria normalized to OC
SQC	=	Sediment Quality C^riteria (μg/kg)
%TOC	=	Percent Total Organic Carbon (expressed as g•OC/kg)

Summary

Results of the WoE analysis are provided in Table 24, below. Consideration of the potential for PAH exposures in fish tissue is required as concentrations lower than the SQC were identified via partitioning theory (0.624 μg/kg). Therefore, during any investigation regarding contamination in sediment due to PAHs the potential for carcinogenic risk relating to fish consumption should also be evaluated.

Table 24	**Dibenzo[a,h]anthracene WoE Evaluation**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** 0.000624 mg/kg

Fluoranthene

An overall screening **SQC value of 0.047 mg/kg** derived for fluoranthene.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.047 mg/kg (REL) (indicating low potential for adverse effect) to a high of 10.2 mg/kg (indicating the level above which the potential for adverse effects is almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 19 and summarized in Appendix A (Table A1).

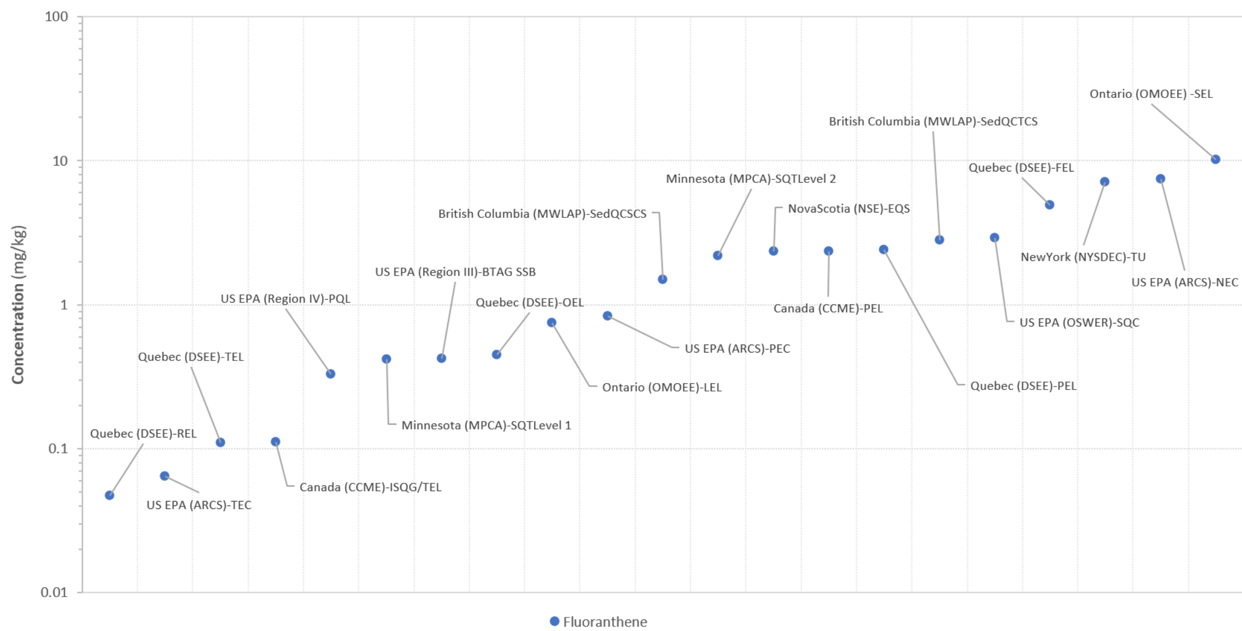

Figure 19. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were available from the SETAC-SEDAG database (SEDAG 2016) but derivation of an SST was not valid since as fluoranthene has the potential to bioaccumulate as discussed below.

Spiked Sediment Toxicity Testing Results - Fluoranthene									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Rhepoxynius abronius	adult	10	survival	LC10	2.9	mg/kg	1,160	0.25	Swartz et al. 1988
Mercinaria mercinaria	juvenile	10	survival	LC50	1.75	mg/kg	302	0.58	Chung et al. 2007
Rhepoxynius abronius	adult	10	survival	LC50	3.1	mg/kg	1,240	0.25	Swartz et al. 1988
Hyalella azteca	juvenile	10	survival	LC50	3.248	mg/kg	829	0.39	Hatch and Burton Jr 1999
Rhepoxynius abronius	Unspecified	10	survival	LC50	3.4	mg/kg	1,889	0.18	Swartz et al. 1997
Rhepoxynius abronius	adult	10	survival	LC50	4.2	mg/kg	1,680	0.25	Swartz et al. 1988
Corophium spinicorne	Unspecified	10	survival	LC50	5.1	mg/kg	2,833	0.18	Swartz et al. 1997
Rhepoxynius abronius	Unspecified	10	survival	LC50	6.5	mg/kg	2,097	0.31	Swartz et al. 1997
Rhepoxynius abronius	Unspecified	10	survival	LC50	10.7	mg/kg	2,229	0.48	Swartz et al. 1997
Rhepoxynius abronius	Unspecified	10	survival	LC50	16	mg/kg	7,400	0.2	Cole et al. 2000
Ampelisca abdita	adult	10	survival	LC50	16.1	mg/kg	2,064	0.78	Anderson et al. 2008
Rhepoxynius abronius	Unspecified	10	survival	LC50	22.1	mg/kg	10,200	0.2	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	22.1	mg/kg	10,200	0.2	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	22.6	mg/kg	10,500	0.2	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	23.1	mg/kg	10,700	0.2	Cole et al. 2000
Ampelisca abdita	adult	10	survival	LC50	24.4	mg/kg	3,128	0.78	Anderson et al. 2008
Rhepoxynius abronius	Unspecified	10	survival	LC50	25.5	mg/kg	11,800	0.2	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	31.8	mg/kg	5,300	0.6	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	32.2	mg/kg	5,400	0.6	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	36.2	mg/kg	6,100	0.6	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	36.6	mg/kg	6,100	0.6	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	37.2	mg/kg	6,200	0.6	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	38.7	mg/kg	6,500	0.6	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	38.8	mg/kg	6,500	0.6	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	39.3	mg/kg	6,600	0.6	Cole et al. 2000
Ampelisca abdita	adult	10	survival	LC50	42.3	mg/kg	5,423	0.78	Anderson et al. 2008
Ampelisca abdita	juvenile	10	survival	LC50	50	mg/kg	Unspecified	Unspecified	Fulton et al. 1999

Rhepoxynius abronius	Unspecified	10	survival	LC50	52.2	mg/kg	24,200	0.2	Cole et al. 2000
Rhepoxynius abronius	Unspecified	10	survival	LC50	59.4	mg/kg	27,600	0.2	Cole et al. 2000
Eohaustorius estuarius	adult	10	survival	LC50	67	mg/kg	8,590	0.78	Anderson et al. 2008
Hyalella azteca	juvenile	10	survival	LC50	69.6	mg/kg	8,136	1.7-2.1	Amweg and Weston 2007
Eohaustorius estuarius	adult	10	survival	LC50	82	mg/kg	10,513	0.78	Anderson et al. 2008
Hyalella azteca	juvenile	10	survival	LC50	99.3	mg/kg	8,510	1.7-2.1	Amweg and Weston 2007
Eohaustorius estuarius	adult	10	survival	LC50	107	mg/kg	13,718	0.78	Anderson et al. 2008

Notes:
LC_{10} -10% reduction in survival to fluoranthene
LC_{25} - 25% reduction in survival to fluoranthene
LC_{50} - 50% reduction in survival to fluoranthene

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. A sediment-to-benthic invertebrate bioconcentration factor was not reported by the US EPA (1999).

Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012). Regardless of this fact, the K_{ow} of select PAH parameters does meet the technical requirements under CEPA (1999) for consideration as bioaccumulating. Fluoranthene has a logK_{ow} of 5.16 and thus the decision was made to derive a screening sediment quality guideline for the protection of human health.

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 3,500 mg/kg for humans and 15.4 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments.

Establish ADI in Fish Tissue:

Based on a TDI of 0.04 mg/kg-day (AEP 2019) the acceptable daily intake (ADI) within fish tissue can be calculated as follows:

$$ADI = \frac{TDI \times AF \times BW}{Fish\ Consumption\ Rate}$$

$$ADI = \frac{0.04\ \times 0.5 \times 16.5}{0.00794}$$

$$ADI = 41.56\ mg/kg$$

Where:

ADI	=	Acceptable Daily Intake (mg/kg)
AF	=	Apportionment Factor (0.5 (AEP 2019))
TDI	=	Tolerable Daily Intake (mg/kg-day)
BW	=	For non-carcinogens a toddler body weight is used (16.5 kg)
FCR	=	Fish Consumption Rate (based on FNFNES 2013) (kg/day)

Determine Baseline BAF from K_{ow}:

$$BAF_{Baseline} = K_{ow} \times FCM$$

$$BAF_{Baseline} = 144{,}544 \times 3.78$$

$$BAF_{Baseline} = 5.46 \times 10^5$$

Where:

BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 5.16)
FCM	=	Food Chain Multiplier (19.4 based on Trophic Level of 3.5)

Determine Freely Dissolved Fraction of Chemical in Water:

$$f_{fd} = \frac{1}{1 + \frac{(DOC)(K_{ow})}{10} + (POC)(K_{ow})}$$

$$f_{fd} = \frac{1}{1 + \frac{(0.000002)(144{,}544)}{10} + (0)(144{,}544)}$$

$$f_{fd} = 0.9719$$

Where:

ffd	=	freely dissolved fraction of a chemical in water
DOC	=	concentration of dissolved organic carbon in water (kg DOC/L)
POC	=	concentration of particulate organic carbon in water (kg POC/L)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 5.16)

Determine the Wildlife BAF from Baseline BAF:

$$BAF_{Trophic\ Level_{3.5}}^{Receptor} = \left[(BAF_{Baseline}) \times \left(\%Lipid_{Trophic\ Level_{3.5}\ Fish}\right) + 1\right]\left(f_{fd}\right)$$

$$BAF_{Trophic\ Level_{3.5}}^{Receptor} = [(5.46 \times 10^5) \times (0.0835) + 1](0.9719)$$

$$BAF_{Trophic\ Level_{3.5}}^{Receptor} = 44{,}519$$

Where:

$BAF_{Trophic\ Level_{3.5}}^{Receptor}$ (Zanden et al., 1996)	=	BAF for consumption of fish from a trophic level of 3.5
BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific) (L/kg)
%Lipidtrophic level	=	%lipid in fish for a given trophic level (8.35%)
ffd	=	freely dissolved fraction of a chemical in water

Determine the BAF-Based Water Quality Value for Porewater:

$$C_{pw} = \frac{ADI}{BAF_{Trophic\ Level_{3.5}}^{Receptor} \times \%\ of\ Diet}$$

$$C_{pw} = \frac{41.56}{44{,}519 \times 100\%}$$

$$C_{pw} = 9.34 \times 10^{-4}\ mg/L\ \ or\ 0.934\ \mu g/L$$

Where:

ADI	=	Acceptable Daily Intake in Fish (mg/kg)
$BAF_{Trophic\ Level_{3.5}}^{Receptor}$ (Zanden et al., 1996) (L/kg)	=	BAF for consumption of fish from a trophic level of 3.5
%Diet	=	Assume 100% of diet is fish from a trophic level of 3.5
Cpw	=	Concentration in Porewater (mg/L)

Calculate the Sediment Guideline for Protection of Fish Tissue Tainting via Equilibrium Partitioning Method:

$$SQC_{OC} = C_{pw} \times K_{oc} \times \frac{1kg}{1,000gOC}$$

$$SQC_{OC} = 0.934 \times 118,184 \times 0.001$$

$$SQC_{OC} = 110.3\ \mu g/gOC$$

Where:

Cpw	=	Concentration in Porewater (µg/L)
Koc	=	Soil Adsorption Coefficient (gOC/g soil)
SQCoc	=	Sediment Quality Criteria (µg/gOC)

Define a Final Sediment Quality Guideline for an Assumed TOC in Sediment of 2%:

$$SQC = SQC_{OC} \times TOC$$

$$SQC_{OC} = 110.3 \times 20$$

$$SQC_{OC} = 2,206\ \mu g/kg \ \ or\ 2.2\ mg/kg$$

Where:

SQCoc	=	Sediment Quality Criteria normalized to OC
SQC	=	Sediment Quality Criteria (µg/kg)
%TOC	=	Percent Total Organic Carbon (expressed as g•OC/kg)

Summary

Results of the WoE analysis are provided in Table 25, below.

Table 25	Fluoranthene WoE Evaluation
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:**

	2.2 mg/kg

Fluorene

An overall screening **SQC value of 0.010 mg/kg** was adopted from Quebec (DSEE) REL for fluorene.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.01 mg/kg (REL) (indicating low potential for adverse effect) to a high of 5.39 mg/kg kg (narcosis and EqP partitioning model indicating concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 20.

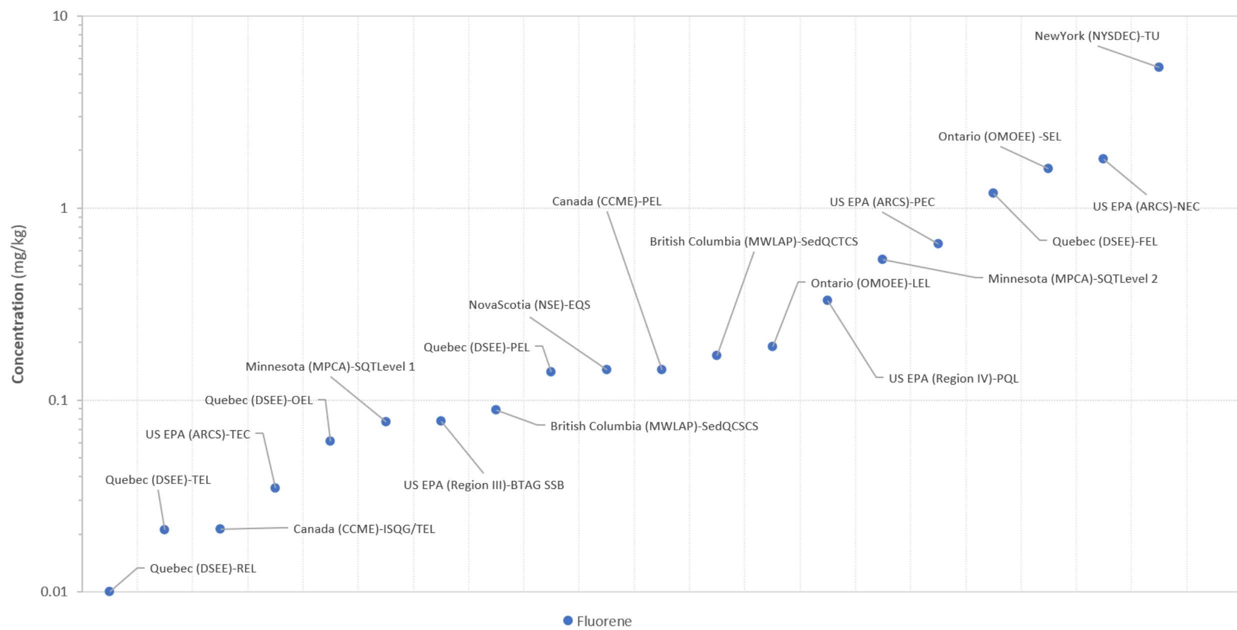

Figure 20. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified for fluorene.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. No sediment-to-benthic invertebrate bioconcentration factor were reported by the US EPA (1999).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 2,700 mg/kg for humans and 15.4 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments.

Summary

The SQC_{low}, SQC_{medium} and SQC_{high}), narrative endpoint for Toxicity and Benthos Alteration and Biomagnification Potential results are provided in Table 26, below.

Table 26	**Fluorene WoE Evaluation**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

2-Methylnaphthalene

An overall screening **SQC value of 0.016 mg/kg** was adopted from Quebec (DSEE) REL for 2-methylnaphthalene.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.016 mg/kg (REL) (indicating low potential for adverse effect) to a high of 0.38 mg/kg kg (FEL) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 21.

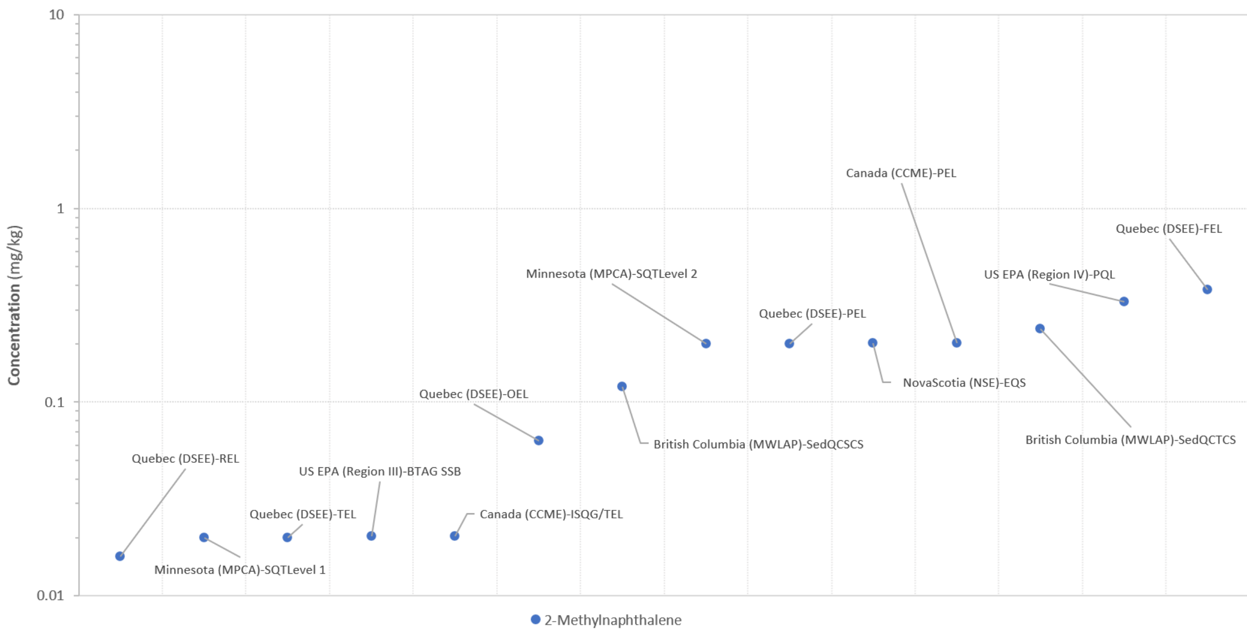

Figure 21. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified for 2-methylnaphthalene.

Direct Soil Contact Receptors Check

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. A sediment-to-benthic invertebrate bioconcentration factor was not reported by the US EPA (1999).

Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012).

Summary

Results of the WoE analysis are provided in Table 27, below.

Table 27	**SQC – 2-Methylnaphthalene**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Naphthalene

An overall screening **SQC value of 0.017 mg/kg** was adopted from Quebec (DSEE) REL for naphthalene.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.017 mg/kg (REL) (indicating low potential for adverse effect) to a high of 23 mg/kg kg (EqP derived conventional chronic aqueous benchmark protective of Daphnids (invertebrates)). Distribution of the SQC values is visually depicted on Figure 22.

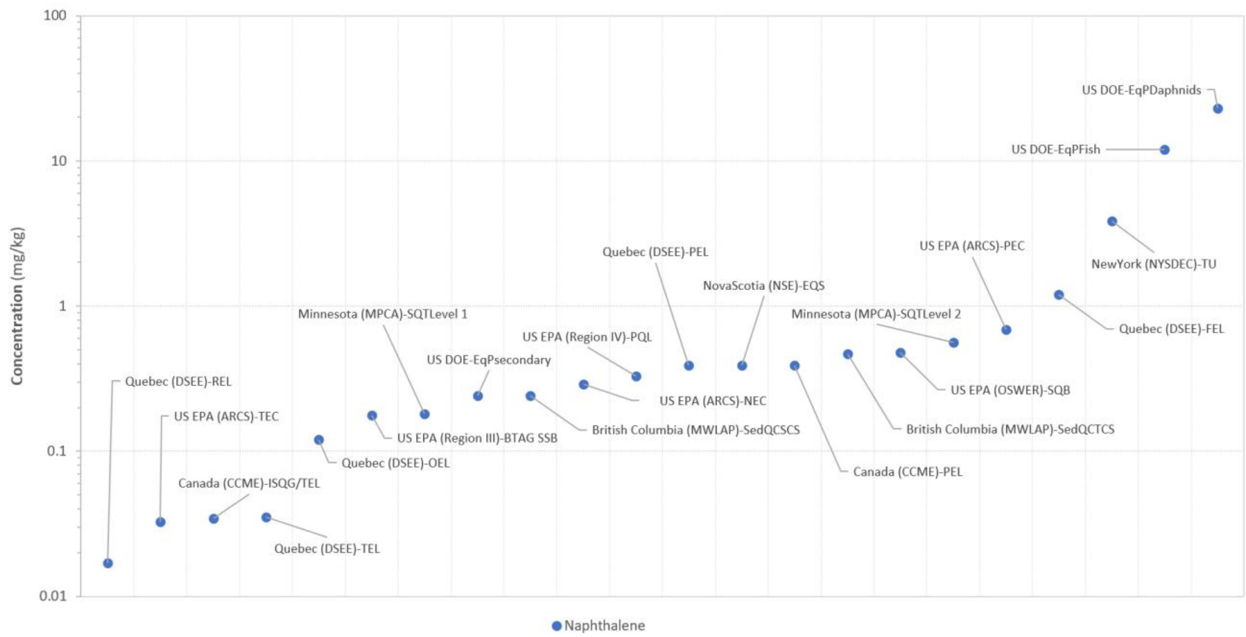

Figure 22. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified for naphthalene.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. A sediment-to-benthic invertebrate bioconcentration factor was not reported by the US EPA (1999).

Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012).

Summary

Results of the WoE analysis are provided in Table 28, below.

Table 28	**Naphthalene WoE Evaluation**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Phenanthrene

An overall screening **SQC value of 0.025 mg/kg** was adopted from Quebec (DSEE) REL for phenanthrene.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.025 mg/kg (REL) (indicating low potential for adverse effect) to a high of 59 mg/kg (EqP derived conventional chronic aqueous benchmark protective of Daphnids (invertebrates)). Distribution of the SQC values is visually depicted on Figure 23.

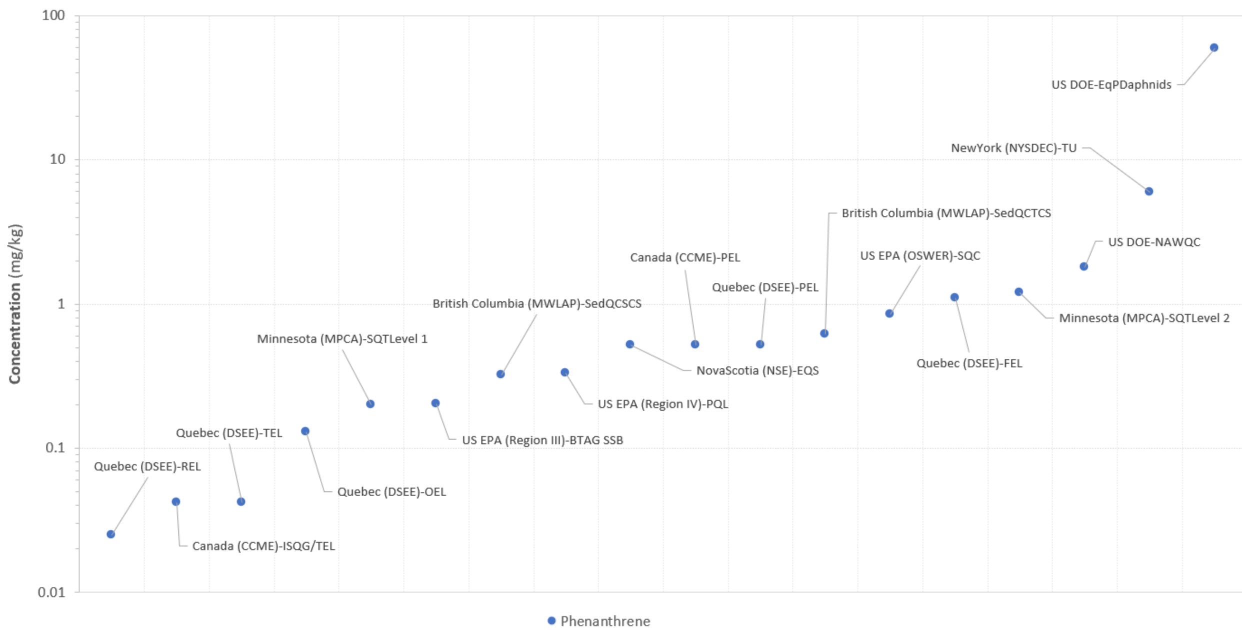

Figure 23. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were available from the SETAC-SEDAG database (SEDAG 2016) but did not support the derivation of an SST benchmark.

Spiked Sediment Toxicity Testing Results - Phenanthrene									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Quinquelaophonte sp	adult	14	reproduction	LOEC	0.037	mg/kg	3.60	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	14	reproduction	EC10	0.0035	mg/kg	0.34	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	14	reproduction	EC20	0.01	mg/kg	0.97	1.03	Stringer et al. 2014
Quinquelaophonte sp	adult	14	reproduction	EC50	0.067	mg/kg	6.50	1.03	Stringer et al. 2014
Rhepoxynius abronius	UN	10	survival	LC50	66.6	mg/kg	2,220	3	Swartz et al. 1990
Rhepoxynius abronius	UN	10	survival	LC50	92.4	mg/kg	3,080	3	Swartz et al. 1990

Notes:

LOEC - lowest observed effect concentration

EC_{10} - 10% reduction in the endpoint (e.g. growth)

EC_{20}- 20% reduction in the endpoint (e.g. growth)

$EC5_{0}$ - 50% reduction in the endpoint (e.g. growth)

LC_{50} - 50% reduction in survival to phenanthrene

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. A sediment-to-benthic invertebrate bioconcentration factor was not reported by the US EPA (1999).

Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health

Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration was not identified for humans. A value of 43 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments.

Summary

Results of the WoE analysis are provided in Table 29, below.

Table 29	**Phenanthrene**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Pyrene

An overall screening **SQC value of 0.029 mg/kg** was adopted from Quebec (DSEE0 REL for pyrene.

Guideline Review

The literature review indicated that SQC values for this chemical range from a low of 0.029 mg/kg (REL) (indicating low potential for adverse effect) to a high of 8.5 mg/kg (SEL) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 24.

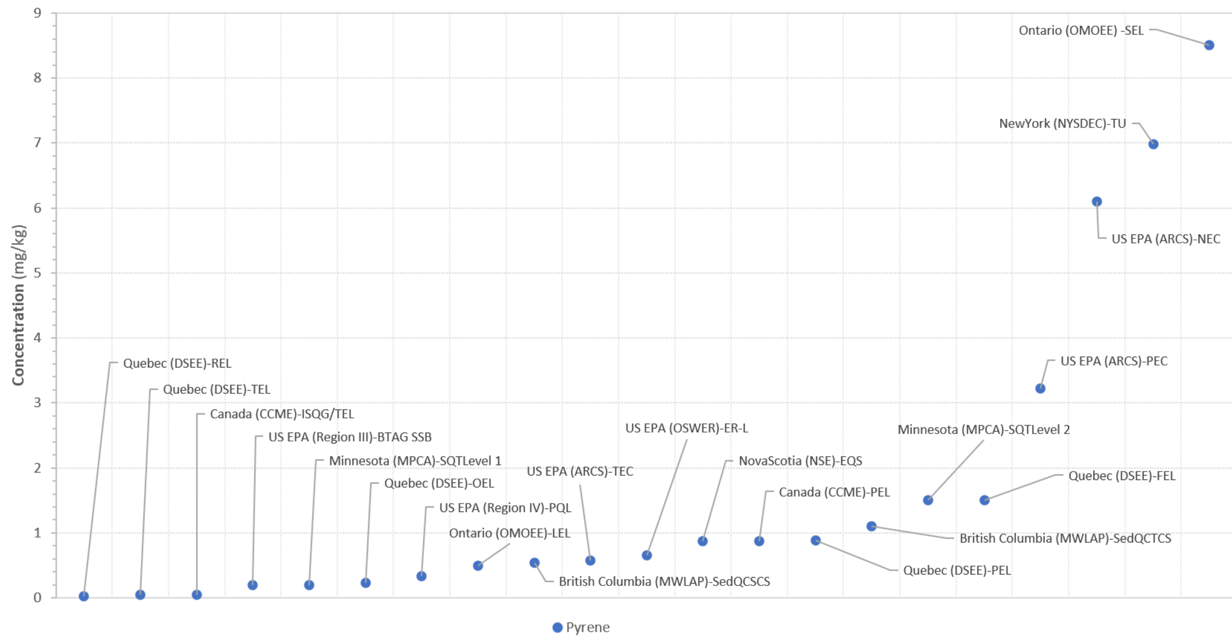

Figure 24. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SST Guideline Derivation

Spiked sediment toxicity values were available from the SETAC-SEDAG database (SEDAG 2016) but did not support the derivation of an SSTT guideline.

Spiked Sediment Toxicity Testing Results - Pyrene									
Test Species	**Lifestage**	**Duration (Days)**	**Endpoint**	**Effect**	**Concentration**	**Units**	**OCNorm (µg/g-OC)**	**TOC (%)**	**Citation**
Rhepoxynius abronius	Unspecified	10	survival	LC50	36.6	mg/kg	1,220	3	Swartz et al. 1990
Rhepoxynius abronius	Unspecified	10	survival	LC50	84.3	mg/kg	2,810	3	Swartz et al. 1990

Notes:

LC_{50} - 50% reduction in survival to pyrene

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified and a BCF was not published by US EPA (1999). Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration of 2,100 mg/kg for humans and a value of 7.7 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments.

Summary

Results of the WoE analysis are provided in Table 30, below.

Table 30	Pyrene
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

Low Molecular Weight PAHs

Low molecular weight (LMW) PAHs are defined as having two to three fused aromatic rings.

An SWC **value of 0.552 mg/kg** was selected for the sum of measured LMW PAHs.

Guideline Review

The literature review indicated that SQC values for this group of chemicals range from a low of 0.552 mg/kg (ER-L) (indicating low potential for adverse effect) to a high of 3.369 mg/kg (PEC) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 25.

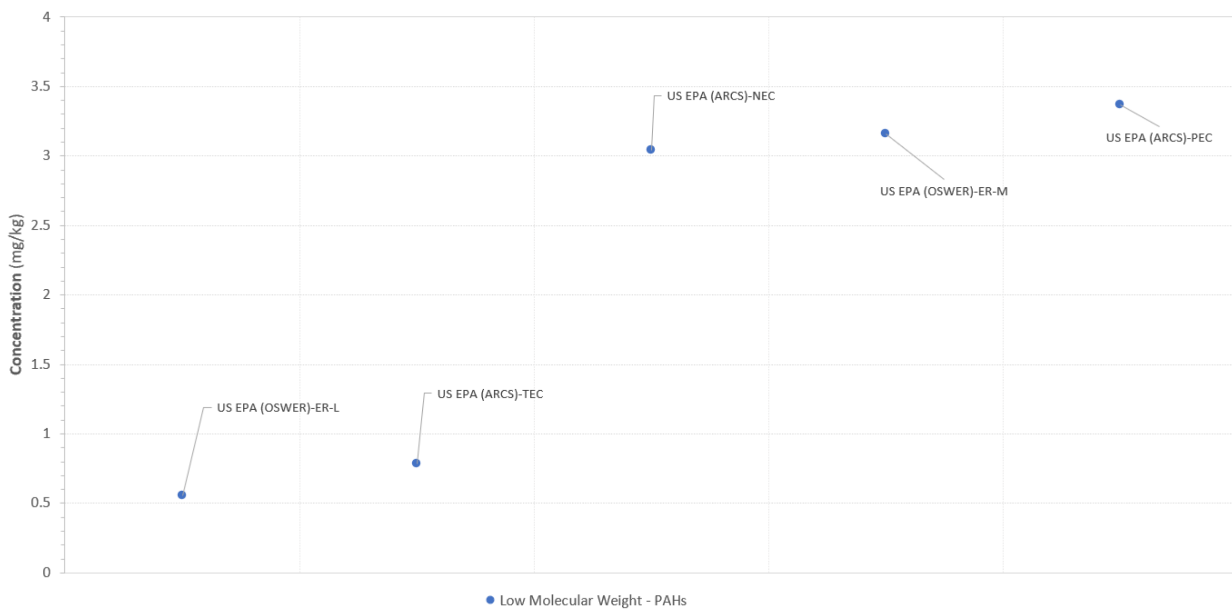

Figure 25. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SST Guideline Derivation

Spiked sediment toxicity values for a full mixture of LMW PAHs was not identified.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted . A screening concentration was not identified for humans. A concentration of 100 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would be inherently protective of higher trophic organisms as it pertains to direct contact and inadvertent ingestion of sediments.

Summary

Results of the WoE analysis are provided in Table 31, below.

Table 31	**Low Molecular Weight PAHs**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

High Molecular Weight PAHs

This group of PAHs includes compounds with four or more fused aromatic rings.

An screening **SQC value of 0.655 mg/kg** was selected for the sum of measured HMW PAHs.

Guideline Review

The literature review indicated that SQC values for this group of chemicals range from a low of 1.7 mg/kg (ER-L) (indicating low potential for adverse effect) to a high of 51 mg/kg (NEC) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 26 and summarized in Appendix A (Table A1).

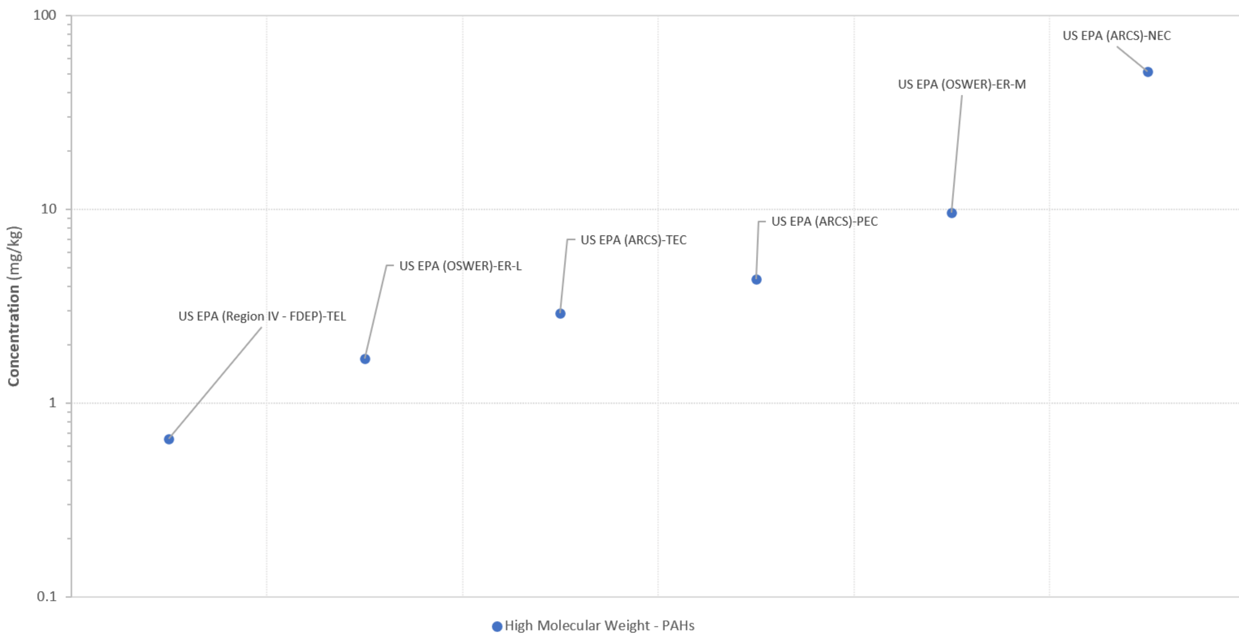

Figure 26. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values for a full mixture of HMW PAHs was not identified.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.,* 2004). However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration was not identified for humans. A concentration of 1.1 mg/kg for wildlife receptors was identified. It should be noted that these values are reflective of terrestrial receptors and terrestrial exposure scenarios. They are presented here as a check function to assess the potential that further consideration of these exposure pathways is warranted. In addressing sediments contaminated by HMW PAH's consideration should be given to the potential that adverse effects may occur in higher trophic organisms (*i.e.*, wildlife receptors).

Summary

Results of the WoE analysis are provided in Table 32, below.

Table 32	**SQC – High Molecular Weight PAHs**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

**US EPA (OSWER) ER-M value (9.6 mg/kg) was higher than the US EPA (ARCS) PEC value (4.36 mg/kg).*

Total PAHs

An overall screening **SQC value 1.684 mg/kg** was selected for the sum of all measured PAHs (total).

Summary

Different number and groups of PAHs have been defined as Total PAHs. The US EPA originally listed 13 PAHs whereas the National Oceanic and Atmospheric (NOAA) identified a list of 23 PAHs.

None of the reviewed guidance documents included alkylated PAHs as part of the total. This is unfortunate as alkylated PAHs tend to be more toxic than the non-alkylated parent PAH (NYSDEC 2004, US EPA 2003).

This section generally relates to the US EPAs 16 designated high priority pollutants: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, Benzo[a]pyrene, benzo[g,h,i]perylene, indeno[1,2,3-c,d]pyrene, and dibenz[a,h]anthracene (Hussar *et al.*, 2012).

For additional detail regarding the evaluation of multiple contaminant exposure in addressing PAHs see the Cumulative Effects Evaluation section of this report.

Guideline Review

The literature review indicated that SQC values for this group of chemicals range from a low of 1.6 mg/kg (SQT_{Level1}) (indicating low potential for adverse effect) to a high of 100 mg/kg (SEL) (concentration above which adverse effects are almost always expected to occur). Distribution of the SQC values is visually depicted on Figure 27.

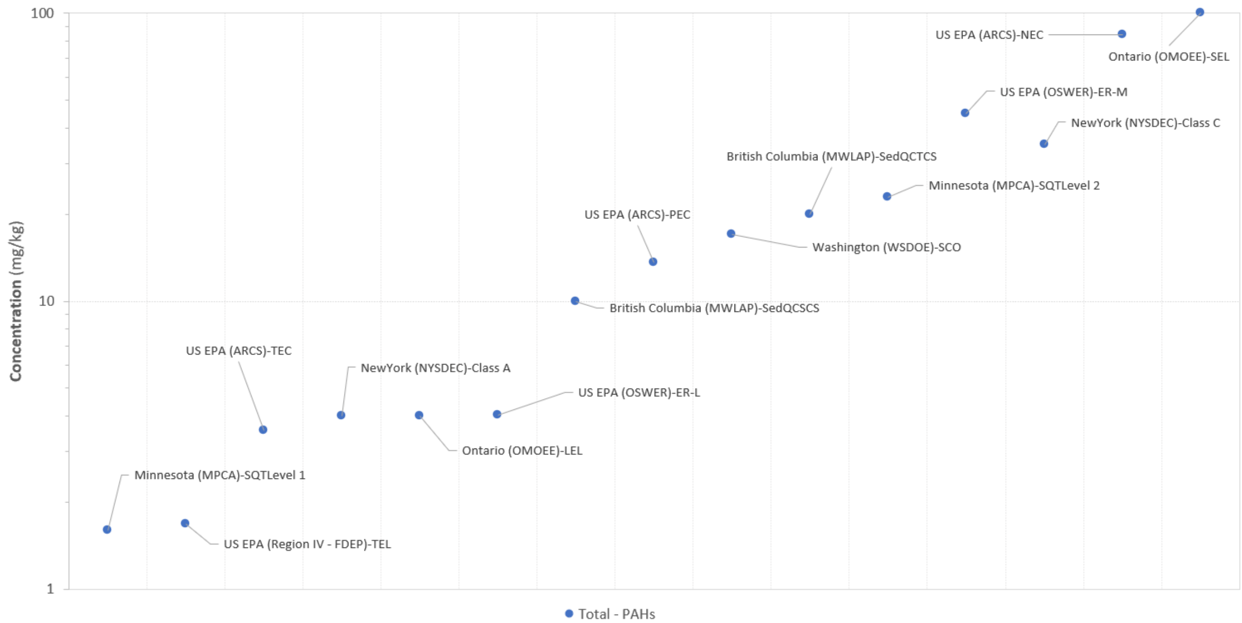

Figure 27. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values for Total PAHs were not identified.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Bioaccumulation in benthic invertebrates has been shown to occur due to limited ability to metabolize these compounds (Rust *et al.*, 2004). However, the potential for PAH biomagnification in higher trophic level species (vertebrates) is considered unlikely; even though these compounds would be expected to bioaccumulate in vertebrate species based on their log K_{ow} values (Eisler R. 1987). This is because PAHs are readily metabolized in vertebrates (Health Canada 2010), and as a result, contaminant potential for biomagnification is considered low (Tudoran 2012, Inomata *et al.*, 2012).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted (Appendix C – Table C1). No values were identified from which to derive a either a human or wildlife screening value.

Summary

Results of the WoE analysis are provided in Table 33, below.

Table 33	**SQC – Total PAHs**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** Chemical is unlikely to biomagnify

**US EPA (OSWER) ER-M value (44.79 mg/kg) was higher than the US EPA (ARCS) PEC value (13.66 mg/kg).*

Chloride

The absence of SQCs for chloride is likely in relation to the high solubility of this compound.

The water quality guideline protective of freshwater aquatic life is 120 mg/L. This guideline may act as a suitable check value for porewater measurements in sediment.

Guideline Review

No SQCs were identified for chloride.

SSTT Derivation

Spiked sediment toxicity values were not identified for chloride.

Direct Soil Contact Receptors Check

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted (Appendix C – Table C1). A screening concentration was not identified for humans or wildlife receptors.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Chloride is not a biomagnifying compound.

Summary

There is insufficient data from which to derive an SQC value for chloride. There are no values available from which to derive SQCs nor conduct a WoE approach for this chemical. The absence of SQCs for chloride is likely in relation to the high solubility of this compound. The water quality guideline protective of freshwater aquatic life is 120 mg/L. This guideline may act as a suitable check value for porewater measurements in sediment.

Naphthenic Acids

A SQC of **3.3 mg/kg** was derived following the US EPA EqPA method, but the value should be used with caution due to the scarcity of data available.

Guideline Review

No SQCs were identified for naphthenic acids.

SSTT Derivation

Spiked sediment toxicity values were not identified within the SETAC-SEDAG database (SEDAG 2016) for naphthenic acids. The review was expanded to include other relevant white-literature resources (published resources) and the grey-literature (white-papers and unpublished work).

A single study was identified which specifically examined the chronic toxicity of naphthenic acid exposure under controlled spiked-sediment study (Howland *et al.*, 2019a). The work was conducted in effort to better understand whether co-contaminant exposure to naphthenic acids and polycyclic aromatic hydrocarbons significantly contribute to or mask survivorship and/or sublethal effects in mayfly (*Hexagenia* spp.) nymphs.

The study did not identify a statistically significant difference in survivorship due to naphthenic acid exposure but sublethal effects were noted in mayflies exposure to the highest concentration tested (1 mg/L). In prior studies, a concentration of 4.3 mg/L was identified as an acute (48-hour) lethal concentration (LC_{50}) (Howland *et al.*, 2019b).

The US EPA (2018) EqPA equation for SQC derivation was selected to derive an SQC_{low}. The equation makes use of several input parameters of which f_{oc}, θ_m, and *pw* are assumed as constants. No published water quality objective/guideline (WQO/G) could be identified in literature for naphthenic acids. In absence of a published WQO/G a safety factor

(SF) of 100 was applied to the sublethal effects concentration reported by Howland *et al.* (2019a). The SF was applied to address limitations in the dataset (SF of 10) and potential for inter- and intra- species differences (SF of 10).

A screening value concentration of 0.01 mg/L (10 μg/L) was thus selected. Calculated K_{oc} values were taken from Gervais (2004). Surrogate chemicals were selected based on commercial availability and distribution of different ring and carbon numbers. Although cycloheptanecarboxylic acid does not have a methyl group, and thus does not fit within the strict definition of a naphthenic acid, its role as an isomer was an important consideration in its inclusion as a surrogate. The K_{oc} values as derived by Gervais (2004) are indicated below (based on a pH of 7).

- Heptanoic acid (2.8)
- 4-Methylcyclohexaneacetic acid (4.3)
- I-Methyl-I-cyclohexanecarboxylic acid (3.9)
- Cycloheptanecarboxylic acid (2.9)
- 4-Pentylbicyclo[2.2.2]octane-I-carboxylic acid (120)
- Octahydro-3-methyl-I-petnalenecarboxylic acid (4.8)
- 3-Methyl-adamantane-I-carboxylic acid (8.4)
- Cholanic Acid (7,900)

An SQC was calculated based on the geomean of the eight surrogate K_{oc}'s (value of 16.4).

$$SQC = WQO/G \times \left(K_{oc} \times f_{oc} + \left(\frac{\theta m}{pw}\right)\right)$$

$$SQC = 10\ (\frac{\mu g}{L}) \times \left(16.4\ \left(\frac{L}{kg}\right) \times 2\% + \left(\frac{0.3}{0.9982}\right)\right)$$

$$SQC = 3{,}283\ \mu g/kg$$

$$SQC = 3.3\ mg/kg$$

Where:

SQC	=	Sediment Quality Criteria (µg/kg)
WQO/G	=	Water Quality Objective/Guideline (µg/L)
Koc	=	Organic carbon partitioning coefficient (L/kg)
Foc g•OC/kg)) g•OC/kg))	=	fraction organic carbon (%OC/kg sediment (e.g., 2% = 20
θm	=	0.3 (assumed as 30% moisture of sediment by mass)
pw	=	0.9982 density of water at 20°C

Based on an assumed K_{oc} of 16.4 and a WQO/G of 0.01 mg/L a screening level SQC of 3.3 mg/kg was derived. This screening value should be used under a weight of evidence approach based on the paucity of available data.

Direct Soil Contact Receptors Check

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. A screening concentration was not identified for humans or wildlife receptors.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified for naphthenic acids.

Summary

There is insufficient data from which to derive an SQC value for naphthenic acids. A screening value of 3.3 mg/kg was derived following the US EPA EqPA method, but the value should be used with caution due to the scarcity of data available.

Phenols

An overall screening **SQC value of 0.23 mg/kg** was derived for phenols based on bioaccumulation and tainting potential in fish tissue.

Guideline Review

The literature review indicated very few SQC values which ranged from a low of 0.42 mg/kg (SSB) to a high of 1.4 mg/kg (ISQC/TEL) (both are considered the concentration under which adverse effects are seldomly expected to occur). There were no higher SQC values identified in literature. Distribution of the SQC values is visually depicted on Figure 35 and summarized in Appendix A (Table A1).

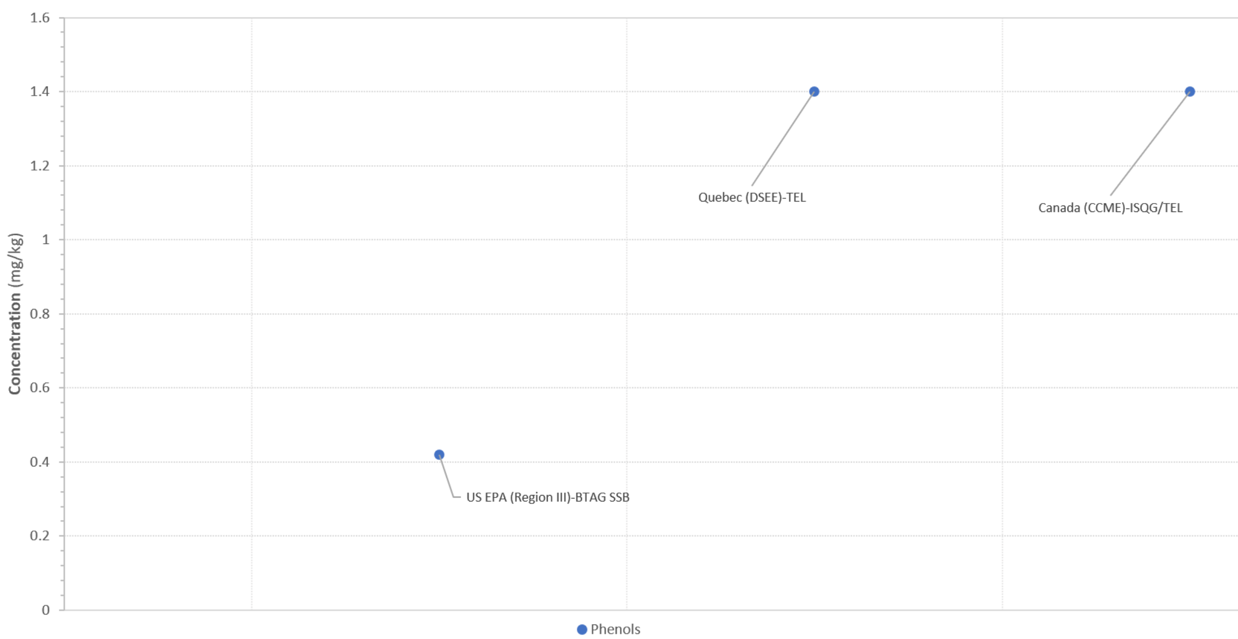

Figure 35. *Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots).*

SSTT Derivation

Spiked sediment toxicity values were not identified within the SETAC-SEDAG database (SEDAG 2016) for phenols.

Direct Soil Contact Receptors Check

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted (Appendix C – Table C1). A screening concentration was not identified for humans or wildlife receptors.

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified for phenols. However, there is a fish tainting concentration in literature of 0.2 mg/kg fish tissue for dimethylphenol in fish tissue (Rogers, V., et. al.,. 2007). This value can be used as an indicator of adverse effects in humans (non-palatability of a food source). It was thus selected as the ADI for fish tissue and an SQC value was derived utilizing the equilibrium partitioning model as described in NYSDEC (2014) and presented below.

Establish ADI in Fish Tissue:

$$ADI = 0.21$$

Where:

ADI = *Acceptable Fish Tissue Concentration (mg/kg)*

Determine Baseline BAF from K_{ow}:

$$BAF_{Baseline} = K_{ow} \times FCM$$
$$BAF_{Baseline} = 28.8 \times 1$$
$$BAF_{Baseline} = 28.8$$

Where:

BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 1.46)
FCM	=	Food Chain Multiplier (assumed as 1)

Determine Freely Dissolved Fraction of Chemical in Water:

$$f_{fd} = \frac{1}{1 + \frac{(DOC)(K_{ow})}{10} + (POC)(K_{ow})}$$

$$f_{fd} = \frac{1}{1 + \frac{(0.000002)(28.8)}{10} + (0)(28.8)}$$

$$f_{fd} = 0.9999$$

Where:

ffd	=	freely dissolved fraction of a chemical in water
DOC	=	concentration of dissolved organic carbon in water (kg DOC/L)
POC	=	concentration of particulate organic carbon in water (kg POC/L)
Kow	=	n-Octanol/Water portioning coefficient (LogKow = 1.46)

Determine the Wildlife BAF from Baseline BAF:

$$BAF^{Receptor}_{Trophic\ Level_{3.5}} = \left[(BAF_{Baseline}) \times \left(\%Lipid_{Trophic\ Level_{3.5}\ Fish}\right) + 1\right]\left(f_{fd}\right)$$

$$BAF^{Receptor}_{Trophic\ Level_{3.5}} = [(28.8) \times (0.0835) + 1](0.9999)$$

$$BAF^{Receptor}_{Trophic\ Level_{3.5}} = 3.42$$

Where:

$BAF^{Receptor}_{Trophic\ Level_{3.5}}$	=	BAF for consumption of fish from a trophic level of 3.5 (Zanden et al., 1996)
BAFbaseline	=	Baseline Bioaccumulation Factor (trophic level specific) (L/kg)
%Lipidtrophic level	=	%lipid in fish for a given trophic level (8.35%)
ffd	=	freely dissolved fraction of a chemical in water

Determine the BAF-Based Water Quality Value for Porewater:

$$C_{pw} = \frac{ADI}{BAF^{Receptor}_{Trophic\ Level_{3.5}} \times \%\ of\ Diet}$$

$$C_{pw} = \frac{0.21}{3.42 \times 100\%}$$

$$C_{pw} = 0.0614\ mg/L\ \ or\ 61.4\ \mu g/L$$

Where:

ADI	=	Acceptable Daily Intake in Fish (mg/kg)
$BAF^{Receptor}_{Trophic\ Level_{3.5}}$ 3.5 (Zanden et al., 1996) (L/kg)	=	BAF for consumption of fish from a trophic level of
%Diet 3.5	=	Assume 100% of diet is fish from a trophic level of
Cpw	=	Concentration in Porewater (mg/L)

Calculate the Sediment Guideline for Protection of Fish Tissue Tainting via Equilibrium Partitioning Method:

$$SQC_{OC} = C_{pw} \times K_{oc} \times \frac{1kg}{1{,}000gOC}$$

$$SQC_{OC} = 61.4 \times 187 \ \times 0.001$$

$$SQC_{OC} = 11.48\ \mu g/gOC$$

Where:

Cpw	=	Concentration in Porewater (µg/L)
Koc	=	Soil Adsorption Coefficient (gOC/g soil)
SQCoc	=	Sediment Quality Guideline (µg/gOC)

Define a Final Sediment Quality Guideline for an Assumed TOC in Sediment of 2%:

$$SQC = SQC_{OC} \ \times TOC$$

$$SQC_{OC} = 11.48 \ \times 20$$

$$SQC_{OC} = 230\ \mu g/kg\ \ or\ 0.23\ mg/kg$$

Where:

SQCoc	=	Sediment Quality Criteria normalized to OC
SQC	=	Sediment Quality Criteria (µg/kg)
%TOC	=	Percent Total Organic Carbon (expressed as g•OC/kg)

Summary

A screening value of 0.42 mg/kg is suggested for addressing potential for risk to aquatic life as the SQC (Table 41). However, consideration of the potential for fish tissue tainting is required as concentrations lower than the SQC were identified via partitioning theory (0.23 mg/kg). Therefore, during any investigation regarding phenol contamination the potential for fish tissue tainting should also be evaluated.

Table 41	**SQC – Phenols**
Toxicity Endpoints (relative to reference)	**Negligible:** Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity (effect endpoints)	**Negligible:** Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	"equivalent" to reference stations.
Biomagnification Potential	**Negligible:** 0.23 mg/kg