Update to Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas RG-263 (Revised)
January 2006 Version

This document incorporates changes made primarily to the ecological screening benchmarks portions of the TCEQ document "Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas RG-263 (Revised)", which was issued in December of 2001. As these revisions are only for selected sections of the ecological risk assessment (ERA) guidance document, the remainder of that guidance remains valid. Also, since the page numbers of these revised sections do not correspond with the page numbers in the ERA guidance document, a page-for-page substitution is not possible (i.e., users will need both documents). The information presented in this update is available immediately and should be used in lieu of the outdated material. As of January 1, 2006, only the updated information is recognized. It is envisioned that if significant changes to other portions of the ERA guidance document become necessary, that the entire document will be revised and reissued.

The primary purpose of these revisions is to update the list of bioaccumulative chemicals of concern (COCs) and the ecological screening benchmarks for surface water, sediment, and soil (Tables 3-1 through 3-4 and Table A-2) and associated text and references. However, revisions were also made to reflect the agency's name change (from TNRCC) and to correct typographical errors. A summary of revisions is included. The vast majority of these changes were directly reviewed and approved by the Ecological Workgroup (a multi-stakeholder group consisting of technical experts from industry, government, consulting firms, and academia). However, a few revisions were made in order to remain consistent with ERA guidance or TCEQ policy and rules (e.g., Texas Risk Reduction Program).

Please contact any of the TCEQ ERA Program staff listed below if you have any questions regarding these revisions or the agency's ERA Program in general.[1]

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[1]This document should be cited as TCEQ. 2006. Update to Guidance for Conducting Ecological Risk Assessments at Remediation Sites In Texas RG-263 (Revised). Remediation Division. January. http://www.tceq.state.tx.us/assets/public/remediation/eco/0106eragupdate.pdf

Summary of January 2006 Revisions

Section 2.6.2 Expedited Stream Evaluation Qualifications

- Updated "Implementation Procedures" reference.

Table 3-1 Bioaccumulative COCs

- Added **Pentachlorophenol** to Table 3-1 for soil and sediment. Eco SSLs for birds and mammals were much lower than for soil invertebrates and plants. Added new footnote "g" to support listing. Note: PCP was not evaluated in the kingfisher exercise because it was not a listed bioaccumulator at the time, but it does have a water quality standard.
- Modified sentence preceding the footnotes to include pentachlorophenol listing.
- For new footnote "g" EPA, 2005 was added directly into the footnote since references for Section 3.4 are not part of this revision package.

Section 3.5.1.1 Derivation of Surface Water Benchmarks Using LC_{50} Data

- Revised criteria used to define persistence from 2 months to 4 days.

Section 3.5.1.2 Derivation of Sediment Benchmarks Using Equilibrium Partitioning

- Revised last two paragraphs to reflect inclusion of EqP-derived sediment benchmarks for VOCs.

Section 3.5.3 Surface Water Benchmarks

- Updated references to the "Guidance for Assessing Texas Surface and Finished Drinking and Water Quality Data", the "Implementation Procedures", and the LC_{50} data from the Water Quality Division.

Section 3.5.4 Sediment Benchmarks

- Revised 2nd paragraph to reflect that MacDonald et al. (2000) is now the primary source of freshwater sediment benchmarks and that the EqP process was used to derive sediment benchmarks for VOCs.
- Revised third paragraph to reflect the new position on evaluating PAHs as mixtures.
- Revised last paragraph to make more current.

Section 3.5.5 Soil Benchmarks

Deleted original last two paragraphs and replaced with new paragraphs 2 through 4. Highlights include:

- Added discussion of Eco-SSLs, derivation process, and references to current Eco-SSL status on new and revised SSLs.
- Noted that SSL documents were issued for **chromium, vanadium** and **dieldrin**, but neither plant nor soil invertebrate values were included.
- Revised list of Eco-SSLs taken from EPA, 2000; still using **copper** and **zinc** values from this document
- Updated hyperlink to Eco-SSL web site.

Table 3-2 Ecological Benchmarks for Water

- **Antimony** - revised freshwater value and deleted marine value.
- **Barium** - revised extremely low freshwater benchmark value and added a marine benchmark based on Water Quality Division LC_{50} calculations.
- **Silver** - added marine benchmark.
- **Thallium** - corrected typographical error.
- **PCB** - revised according to Texas Surface Water Quality Standards.
- **Magnesium, Acrolein, 2-Methylnaphthalene, Naphthalene**, and numerous semi-volatiles and volatiles were revised according to Water Quality Division procedures.
- Added benchmarks for **Bis (chloroisopropyl) ether, Bis (2-ethyl-hexyl)phthalate,** and **Bis (n-octyl) phthalate**; deleted benchmark for **Di-n-octyl phthalate**.
- Updated and revised footnotes and references according to changes listed above.

Table 3-3 Ecological benchmarks for Sediment

- Freshwater sediment benchmarks and footnotes were revised to reflect that MacDonald et al. (2000) is now the primary source.
- The footnotes for **PAHs** were revised to reflect the new position on evaluating PAHs as mixtures, to be consistent with the TRRP rule, and to correct previous typos. Also, the comment *"Footnote (i) applies to all listed PAHs"* was added beside the subtitle "**Polycyclic Aromatic Hydrocarbons (mg/kg dry wt.)".**
- Benchmarks for organophosphates and other pesticides were added.
- Sediment benchmarks derived from the EqP method were added for **VOCs** and the comment "*Footnote (n) applies to all listed volatiles*" was added beside the subtitle **"Volatiles (mg/kg dry wt.)".**
- Footnote "e" was added to **BHC** and **Sums DDE, DDD, and DDT** to reflect that they are sums and are subject to proxy values. Other footnotes were revised according to the changes listed above.

Table 3-4 Ecological Benchmarks for Soil

- **Aluminum** - deleted plant benchmark and replaced with footnote referencing Eco-SSL.
- **Antimony** - added soil invertebrate screening level and updated citation (new date) for footnote "e": U.S. Environmental Protection Agency. Ecological Soil Screening Levels for Antimony. Interim Final. OSWER Directive 9285.7-61. February 2005.
- **Arsenic** - there is still no Eco-SSL invertebrate value but the plant benchmark has changed to 18 mg/kg from 37 mg/kg and a new footnote/citation "m" was added: U.S. Environmental Protection Agency. Ecological Soil Screening Levels for Arsenic. Interim Final. OSWER Directive 9285.7-62. March 2005.
- **Barium** - added soil invertebrate screening level and updated citation, footnote "h": U.S. Environmental Protection Agency. Ecological Soil Screening Levels for Barium. Interim Final. OSWER Directive 9285.7-63. February 2005.
- **Beryllium** - added soil invertebrate screening level and updated citation for footnote "i": U.S. Environmental Protection Agency. Ecological Soil Screening Levels for Beryllium. Interim Final. OSWER Directive 9285.7-64. February 2005.
- **Cadmium** - plant value changed to 32 mg/kg from 29 mg/kg. Updated citation now

includes soil invertebrates and plants so footnote "g" was removed from the plant value and footnote "j" was applied to both invertebrate and plant: U.S. Environmental Protection Agency. Ecological Soil Screening Levels for Cadmium. Interim Final. OSWER Directive 9285.7-65. March 2005.

- **Chromium** - there is a new document for chromium that indicates there is not enough data to derive an eco SSL for plants or invertebrates. The 5 mg/kg plant value (and footnote) was removed as it appears to no longer be EPA's position and replaced with ORNL value of 1 mg/kg. U.S. Environmental Protection Agency. Ecological Soil Screening Levels for Chromium. Interim Final. OSWER Directive 9285.7-66. March 2005.
- **Cobalt** - updated citation for footnote "k", which is: U.S. Environmental Protection Agency. Ecological Soil Screening Levels for Cobalt. Interim Final. OSWER Directive 9285.7-67. March 2005.
- **Lead** - new eco SSLs issued, invertebrate value is 1,700 mg/kg and plant value is 120 mg/kg. This will be new footnote "n": U.S. Environmental Protection Agency. Ecological Soil Screening Levels for Lead. Interim Final. OSWER Directive 9285.7-70. March 2005.
- **Thallium** - original values were for thorium; replaced thallium with thorium.
- **Pentachlorophenol** - new eco SSLs were issued, plant value is 5.0 mg/kg and invertebrate value is 31 mg/kg. These replace ORNL soil benchmarks of 6 mg/kg for plants and 3 mg/kg for invertebrates. New citation is: U.S. Environmental Protection Agency. Ecological Soil Screening Levels for Pentachlorophenol. Interim Final. OSWER Directive 9285.7-58. March 2005.

<u>Section 3.6.1 Communities</u>

- 4th and 5th bullets revised to exclude tidal tributaries to segments 1006 and 1007.

<u>Section 3.13.2 Selection of Comparative and Final Ecological PCLs</u>

- Guideline 1) - qualified 1st sentence and referred to guideline 6).
- Guideline 6) - revised 1st and 2nd paragraphs to reflect that MacDonald et al. (2000) is now the primary source for freshwater sediment benchmarks, that TECs replace PECs, and that the midpoint is no longer a default for developing sediment PCLs for benthics when data suggests that it will not be protective.

<u>Box 3-7</u>

- Last sentence in box was added to reflect Fuchsman (2003) modification of EqP method. Reference was also added.

<u>Section 6.3 Equilibrium Partitioning</u>

- Fuchsman (2003) reference was added.

<u>Section 7.0 REFERENCES</u>

- Previously mentioned references were updated/added as appropriate.

APPENDIX A: Derivation of the Ecological Screening Benchmarks

Several changes were made. Highlights include:

- Citations were updated.
- Example Aquatic Life Calculation Using the LC50 Approach for Chloroform - revised criteria used to define persistence from 2 months to 4 days.
- Freshwater Sediment Benchmarks - added sentence about using the EqP method and Fuchsman (2003) modification to derive sediment benchmarks for VOCs.
- Equilibrium Partitioning Approach - added sentence about using the EqP method and Fuchsman (2003) modification to derive sediment benchmarks for VOCs.
- Using Sediment Benchmarks to Derive PCLs for Benthic Communities - added sentence to reflect that MacDonald et al. (2000) is now the primary source of freshwater sediment benchmarks. Also added a statement that the midpoint is no longer a default for developing sediment PCLs for benthics when data suggests that it will not be protective. Also added language about the EqP approach, the DiToro et al. (2000) method, and an example calculation box.

Table A-2 Second Effects Levels for Sediment

- Freshwater sediment benchmarks and footnotes were revised to reflect that MacDonald et al. (2000) is now the primary source.
- The footnotes for **PAHs** were revised to reflect the new position on evaluating PAHs as mixtures, to be consistent with the TRRP rule, and to correct previous typos. Also, the comment *"Footnote (j) applies to all listed PAHs"* was added beside the subtitle "**Polycyclic Aromatic Hydrocarbons (mg/kg dry wt.)".**
- Footnote "i" was added to **BHC** and **Sums DDE, DDD, and DDT** to reflect that they are sums and are subject to proxy values.
- Sediment benchmarks derived from the EqP method were added for **VOCs**, the comment "*Footnote (n) applies to all listed volatiles*" was added beside the subtitle **"Volatiles (mg/kg dry wt.)"**, and footnote "o" was added where appropriate.

Appendix A - Soil Benchmarks

- Modified 1st sentence of 2nd paragraph to reflect the new Eco-SSL documents.

References for Appendix A

- Added citations for Eco-SSL documents that were a source of benchmarks.

2.6.2 Expedited Stream Evaluation Qualifications

According to the Implementation Procedures (TCEQ, 2003) as amended, an "intermittent" stream is one which has a period of zero flow for at least one week during most years and is considered "intermittent with perennial pools" when adequate pools persist that would be expected to provide habitat for significant aquatic life use. Determination of perennial pool designation is done on a case- by-case basis using available data and best professional judgement. As discussed in Section 3.6.1, an intermittent stream without perennial pools associated with the affected property may already qualify for not having the person develop a sediment PCL for protection of the benthic community. If the intermittent stream in question does not support a protectable benthic community, then this stream may also qualify for not having the person develop an ecological PCL for upper trophic level receptors because of a lack of associated habitat and receptors. As illustrated in Figure 2-2a, to ascertain whether or not an expedited stream evaluation is appropriate, the following conditions must <u>all</u> be met:

- The stream is intermittent (dries up completely at least one week a year) without perennial pools. (Intermittent streams with perennial pools are defined at §307.3 (a), as amended and discussed in the Implementation Procedures (TCEQ, 2003), as amended.)
- The stream is located in a disturbed area (generally, such situations occur in predominantly urban or commercial/industrial settings).
- The stream meets the acute water quality criteria specified in Table 1 of 30 TAC §307.6 or appropriate surrogate values if there is no criteria specified.
- There is a lack of appreciable instream, edge, or riparian habitat, forage, or shelter in or along the watercourse.
- The watercourse or surrounding vicinity is not known to serve as habitat, foraging area, or refuge to threatened/endangered or otherwise protected species.
- The area is not consistently or routinely used as valuable habitat for natural communities including birds, mammals, reptiles, etc.
- There are no impacts immediately evident in downstream areas where habitat is more likely to support wildlife.

As discussed in Section 2.6.4, compliance with these conditions should be supported by photographic evidence. However, if all of these conditions are met, the stream does not need any further evaluation unless, as discussed in the following section, more thorough downstream analyses reveal impacts. In this case, the stream may need to be evaluated as a potential secondary source of COCs. If any one of these conditions is not met, then the person will need to conduct a Tier 2 SLERA that includes the water body in question, as well as any downstream resources that may be impacted.

The information presented in the case example in Section 2.5 can be used to illustrate this process. The ditch is definitely intermittent and because it is man-made, does not likely have perennial pools. The surrounding area is commercial/industrial and therefore disturbed. Water samples collected from the ditch indicate that acute criteria are being met. Because of the nature of the ditch and the fact that the bank vegetation has been mostly cleared, there is no habitat to be utilized by potential receptors. The horned lizard observed at the facility of the affected property is being addressed via the reasoned justification. Assuming that there is no evidence of downstream impacts, this ditch qualifies for an expedited stream evaluation.

Table 3-1. Bioaccumulative COCs

CAS #	COC	
	Metals	**Applicable Media**
7440-43-9	Cadmium [a, b]	Sediment, Soil
7440–47-3	Chromium [a]	Soil
7440-50-8	Copper [a]	Sediment, Soil
7439-92-1	Lead [a]	Soil
7439-97-6	Mercury [c]	Water, Sediment, Soil
744–02-0	Nickel [a]	Sediment, Soil
7782-49-2	Selenium [a, d]	Water, Sediment, Soil
7440-28-0	Thallium [e]	Water
688-73-3	Tributyltin [a]	Sediment
7440-66-6	Zinc [a, b]	Sediment, Soil
	Organochlorine Pesticides	
309-00-2	Aldrin [a]	Sediment, Soil
57-74-9	Chlordane [a]	Sediment, Soil
72-54-8	DDD [e, f]	Water, Sediment, Soil
72-55-9	DDE [e, f]	Water, Sediment, Soil
50-29-3	DDT [c, f]	Water, Sediment, Soil
60-57-1	Dieldrin [a]	Sediment, Soil
72-20-8	Endrin [a, b]	Sediment, Soil
76-44-8	Heptachlor [a, b]	Sediment, Soil
1024-57-3	Heptachlor epoxide [a]	Sediment, Soil
8001-35-2	Toxaphene [a, b]	Sediment, Soil
	Other Pesticides and PCBs	
2385-85-5	Mirex [a]	Sediment, Soil
3980-114-4	Photomirex [a]	Sediment, Soil
1336-36-3	PCBs [c]	Water, Sediment, Soil
	Other Semi-Volatiles	
none	Dioxins [e]	Water, Sediment, Soil
none	Furans [e]	Water, Sediment, Soil
118-74-1	Hexachlorobenzene [e]	Water, Sediment, Soil
608-73-1	Hexachlorocyclohexanes [a]	Sediment, Soil
29082-74-4	Octachlorostyrene [e]	Water, Sediment, Soil
87-86-5	Pentachlorophenol [g]	Sediment, Soil

The following footnotes pertain to how the belted kingfisher food chain evaluation exercise may affect the “Water” listing of the COCs in Table 3-1 and the listing of pentachlorophenol for sediment and soil:

[a] Evaluated as part of the belted kingfisher exercise but not retained for “Water” because the LOAEL HQ did not exceed 1.

[b] NOAEL HQ of 1 was exceeded and may warrant food chain evaluation depending on site-specific circumstances.

[c] Evaluated as part of the belted kingfisher exercise and retained for "Water" because the LOAEL HQ of 1 was exceeded.

[d] Water listing based on site experience and professional judgment of ecological workgroup.

[e] Not evaluated in the belted kingfisher exercise because there is no state-adopted aquatic life water quality standard.

[f] DDT and its metabolites (DDD and DDE) need to be evaluated cumulatively (i.e., use hazard index approach) and are therefore all listed for water.

[g] Pentachlorophenol is listed for sediment and soil based on its Log K_{ow} of 4.74, and Ecological Soil Screening Levels provided in U.S. EPA. *Ecological Soil Screening Levels for Pentachlorophenol*. Interim Final. OSWER Directive 9285.7-58. March 2005, indicating the potential for risk to birds and mammals at soil concentrations significantly below levels protective of plants and soil invertebrates.

3.5 Ecological Screening Benchmarks

3.5.1.1 Derivation of Surface Water Benchmarks Using LC_{50} Data

The Texas Surface Water Quality Standards - TSWQS (30 TAC §307.6(c)(7), as amended - TNRCC, 2000b) provide a mechanism for deriving numerical criteria where there are no standards and there is insufficient data available to use EPA guidelines (e.g., *Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and Its Uses*; 45 FR 79341 November 28, 1980 (Appendix B), and 50 FR 30784, July 29, 1985 (see Item 10 and Appendix B)). Depending on the persistence and bioaccumulative nature of the COC in question, the TSWQS specify that a multiple of the LC_{50} for the most sensitive aquatic organism may be used:

- For non-persistent COCs, chronic criteria = (LC_{50}) (0.10);
- For persistent COCs that do not bioaccumulate, chronic criteria = (LC_{50}) (0.05); and
- For persistent COCs that bioaccumulate, chronic criteria = (LC_{50}) (0.01).

In selecting toxicity data to calculate a value, LC_{50} test results are preferred, and marine or freshwater (depending on the nature of the receiving water) species indigenous to Texas should be used whenever possible. Results from aquatic plant and algae toxicity tests will not usually be accepted (TCEQ, 2003a) unless the toxicity of the COC is primarily herbicidal. Additionally, flow-through tests with exposure times of 48 hours (for invertebrates) or 96 hours (for vertebrates) are preferred, but static test results can be used particularly where the data indicates a higher sensitivity. If the toxicity test data does not meet the former criteria, the person should justify, as much as possible, the rationale behind toxicity test data selection. Generally, the most conservative LC_{50} should be used that meets the selection preferences indicated. If more than one LC_{50} data point is available for a species, the geometric mean should be calculated. If the LC_{50} approach is used, the person should provide some rationale for the selection of the LC_{50} data point(s). The EPA (U.S. EPA, n.d.) AQUIRE data base may be used for sources of aquatic toxicity data, although it is certainly not the only source of toxicity data. The AQUIRE data base is now available free of charge at the following web site: http://www.epa.gov/ecotox/. Where possible, it is suggested that the user obtain the original paper associated with the AQUIRE reference, and should review the documentation and control codes assigned to the reference (U.S. EPA, 1998). The source paper should be indicated (and preferably reviewed), rather than simply providing the AQUIRE data base reference number alone as a reference for the toxicity data.

Selection of the appropriate multiplier for the calculation is a function of persistence and of the tendency for that material to bioaccumulate. For purposes of this alternate and/or proposed criteria calculation, COCs are considered persistent if the half-life in water or sediment is 4 days or greater, and COCs are considered bioaccumulative if the BCF (bioconcentration factor) or BAF (bioaccumulation factor) for the constituent (measured or estimated using regression analysis) is greater than or equal to 1,000 (TCEQ, 2003a). BCFs or BAFs determined from

laboratory or field studies using water column invertebrates or fish are preferred over estimated values. A range of BCF or BAF values may be presented. The person should use half-lives or environmental fate rate constants (e.g., volatilization, photolysis, hydrolysis, biodegradation) that are most appropriate for the surface water or sediment exposure pathway in question. A range of half-life values may be presented. The person should provide a brief justification regarding the selection of the BCF/BAF and half-life information used in these decisions, and the reference source should be indicated. An example of the process for deriving an aquatic life protection value for chloroform using this approach is provided in Appendix A.

3.5.1.2 Derivation of Sediment Benchmarks Using Equilibrium Partitioning

The ecological workgroup discussed the utility of the equilibrium partitioning (EqP) approach for developing sediment benchmarks, particularly for chemicals where other "preferred" benchmarks were unavailable from common and generally accepted sources. The EqP approach may be desirable as a utility for this purpose, because the chemical-specific partitioning coefficients necessary for the application of EqP are generally either known or fairly easily estimated, based on literature values. The approach (U.S. EPA, 1993f; Di Toro et al., 1991; DiToro and McGrath, 2000) provides a means to calculate a bulk sediment COC concentration benchmark for a single non-polar hydrophobic organic constituent by predicting the bioavailability of COCs sorbed to sediments.

The theory assumes that the amount of organic carbon in a system generally determines the extent of COC partitioning between the sediment particles, pore water, and dissolved organic carbon. The theory predicts that if all phases are at equilibrium, the bioavailability of a constituent should be directly proportional to COC activity in interstitial water, and inversely proportional to the organic carbon content in the sediment since organic carbon controls, to a large degree, the sorption of sediment particles. Thus the sediment pore water concentration and the bulk sediment constituent concentration are related by the carbon-normalized sediment water partition coefficient (K_p) which depends on the sediment particle organic carbon partition coefficient K_{oc} (L/kg oc), and the mass fraction of organic carbon (kilograms oc per kilogram sediment) in sediment:

$K_p = f_{oc} \times K_{oc}$.

The K_{oc} is the partitioning coefficient of a COC to organic carbon, and is used to describe the distribution of COC between the organic fraction of sediment and the interstitial water. The sediment benchmark, SQB, (µg COC/ kg sediment, dry weight) can be determined using the partitioning coefficient K_p, in L/kg between sediment and interstitial water:

SQB (in µg/kg) = K_p x WQC, where WQC (µg/L) is the water quality final chronic value or similar value.

Where K_{oc} is unavailable, it can be estimated using the octanol-water partition coefficient (Di Toro et al., 1991):

$\log_{10} (K_{oc}) = 0.00028 + 0.983 \log_{10} (K_{ow})$.

These equations are provided for general information. The person should use the log K_{ow} and log K_{oc} values specified in the TRRP rule in Figure 30 TAC §350.73(e).

Finally, the SQB = f_{oc} x K_{oc} x WQC.

The principle advantages of this approach are that it allows for the derivation of COC-specific sediment benchmarks (and PCLs where appropriate; see Section 3.13.2,), and the methodology can be adapted to site conditions by adjusting the organic carbon parameter. EPA used this methodology to develop draft sediment quality criteria for acenaphthene, phenanthrene, fluoranthene, dieldrin, and endrin (U.S. EPA, 1993a-e) although the proposed criteria were never adopted. The EqP methodology is applicable for sediments with a f_{oc} value between 0.2 - 12% (U.S. EPA SAB, 1992) and has been tested on non-ionic organic compounds with Log K_{ow} between 3.8 and 5.3 (U.S. EPA, 1997). Although published EqP values have been derived for freshwater environments, the method also has been used for marine environments (Swartz, et al., 1990; Swartz, 1999; and Boese et al., 1999).

Regarding the limitations of this approach, there is uncertainty with the value of the K_{ow} selected, how it was derived (same for f_{oc}), and its use as a predictor of K_{oc} because it is experimentally derived and organic matter in sediment can have different binding capacities (again, the person should use the log K_{ow} and log K_{oc} values specified in the TRRP rule in Figure 30 TAC §350.73(e)). The method assumes that organic carbon is a predominant sorption phase for non-ionic organic COCs in sediments although other characteristics (other than organic carbon concentration) may also control sorption of nonionic organic COCs (grain size, dissolved organic carbon, mineralogy, source of the organic carbon, and molecular structure and surface area of the organic carbon). The method also assumes that partitioning of the organic COC between organic carbon and the pore water is stable at equilibrium. Finally, the methodology assumes that the COC concentrations in interstitial water are acceptable predictors of adverse ecological effects. In other words, it assumes that the sensitivities of benthic species and species used to drive the water quality criteria (primarily water column organisms) will be similar. This may be an inappropriate assumption for tube-dwelling organisms where exposure is primarily at the sediment-water interface or for organisms where sediment ingestion is a primary exposure route (Kaag, et al., 1997).

Similarly, the methodology has not been extensively field validated, was primarily developed using acute toxicity tests with single compounds, and the method uncertainty has not been adequately evaluated. Since water quality criteria or similar benchmarks are used to derive the sediment benchmark using this approach, the methodology is limited by the availability of water quality criteria. Although descriptions of all the components and assumptions built into the EqP approach are beyond the scope of this guidance, a full understanding of the intricacies of this approach will be needed to apply and defend its use outside of the discussion below on volatile compounds. (Box 3-7 in Section 3.13.2 further discusses the advantages and disadvantages of

using an EqP approach.)

Although the agency remains somewhat skeptical about the appropriateness of using EqP to derive sediment benchmarks to protect the benthic community - primarily due to the lack of addressing the sediment ingestion exposure pathway - it does recognize that EqP may be more applicable to certain classes of COCs. Therefore, the ecological workgroup evaluated the use of EqP to derive sediment benchmarks for volatile organic chemicals (VOCs). It is believed that the EqP process may be more appropriate for volatiles since these chemicals are expected to be more water soluble and available in the pore water than more hydrophobic chemicals that are bound to sediment particles (where ingestion of sediment would be a pathway of concern for benthic invertebrates). As presented below, the workgroup used the EqP equation modifications for volatiles suggested by Fuchsman (2003) and the TCEQ LC_{50}-based surface water screening values to calculate sediment benchmarks for these COCs:

$$\text{SQB (mg/kg)} = \text{WQB (mg/L)} \times \left[\left(f_{oc} \, x \, K_{oc} \right) + \frac{1 - f_{solids}}{f_{solids}} \right]$$

Where:

SQB = sediment quality benchmark (mg/kg)
WQB = water quality benchmark (mg/L)
K_{oc} = organic carbon partition coefficient (unitless)
f_{oc} = fraction organic carbon (0.01 kg OC/kg sediment, TRRP-24 default)
f_{solids} = fraction solids (= 1-porosity; porosity = 0.37, TRRP-24 default)

These EqP-derived sediment benchmarks for VOCs appear in Table 3-3. The person should remember that even though surface water benchmarks are used as input, the resulting sediment benchmark values are not effects-based for benthics. Additional discussion of EqP-based benchmarks appears in Section 3.13.2 and Appendix A.

3.5.3 Surface Water Benchmarks

This section discusses the selected benchmarks for surface water (presented in Table 3-2). More details regarding the selection of the water benchmarks in Table 3-2 are provided in Appendix A. Figure 3-4 depicts the preferred hierarchy for selecting ecological screening benchmarks for water. The benchmarks for surface water are intended to be protective of aquatic biota and are not necessarily protective of mammalian and avian receptors that may be exposed to COCs through ingestion of contaminated prey or water.

The State of Texas Surface Water Quality Standards (TNRCC, 2000b), as amended, will serve as the primary benchmarks for surface water, or in absence of a state standard, the most current federal National Ambient Water Quality Criteria (NAWQC) will be used (U.S. EPA, 2000). Current information on the standards can be obtained through the following link: http://www.tceq.state.tx.us/permitting/water_quality/wq_assessment/standards/WQ_standards_2000.html. Where state or federal criteria are available, they must be used. Since a comparison of affected property concentrations to benchmarks in required element (1) is intended to be a screening step, the chronic criteria for the protection of aquatic life are used. Acute criteria may be applied (as appropriate), given the aquatic life uses of the receiving water, at a later stage in the SLERA. The TSWQS define marine waters (or salt water) as coastal waters which have measurable elevation changes due to normal tides and further specifies that marine waters are generally considered to be coastal waters which typically have salinities of two parts per thousand or greater in a significant portion of the water column. This definition should primarily be used to select the appropriate freshwater or marine water quality benchmark. Additionally, a water body is considered tidally influenced when there is observed tidal activity, total dissolved solids are greater than or equal to 2,000 mg/L, or specific conductance is greater than or equal to 3,077 umhos/cm (TCEQ, 2004). Freshwater and marine benchmarks should not be used interchangeably where a benchmark is unavailable for the appropriate medium. Hence, the use of marine benchmarks for highly saline, yet inland, waters in West Texas is not appropriate. Some coastal water bodies may experience tidal elevation changes, yet support a freshwater community due to marginal salinity levels. In such cases, the person may use freshwater sediment and water benchmarks provided that information is presented to demonstrate that the water body supports freshwater organisms.

For a number of metals, the fresh water criterion is a function of hardness. The use of site-specific or default hardness values is discussed in Appendix A. Specific numerical aquatic life criteria for metals and metalloids apply to dissolved concentrations where noted. Dissolved concentrations can be estimated by filtration of samples prior to analysis, or by converting from total recoverable measurements in accordance with procedures approved by the commission in the latest revision of the TCEQ's Implementation Procedures (TCEQ, 2003). This methodology is discussed in Appendix A. The TCEQ prefers dissolved metals data for surface waters, where appropriate, rather than the use of the mathematical conversion.

The person should also be aware that the TSWQS define (Appendix E, Figure 30 TAC

§307.10(5)) site-specific criteria for aquatic life protection for selected water bodies. As these values are higher (less conservative) than those provided in Table 3-2, the person should determine if there is a site-specific standard for the surface water (and COC) in question.

Since the number of COCs for which state or federal water quality criteria are defined is minimal, the ecological workgroup sought out sources for other benchmarks for COCs that do not have specified criteria. Four primary sources were used for the derivation of these other water quality benchmarks. Based on the workgroup's preferred order of use of these sources, Table 3-2 reflects the one number (if available) that should be used for comparison to the affected property surface water data. As indicated, the preferred hierarchy for surface water benchmarks is presented in Figure 3-4. The workgroup first derived chronic default values for aquatic life for selected COCs using the LC_{50} approach discussed in Section 3.5.1.1. As indicated previously, an example derivation of this process is provided in Appendix A. A full discussion of each value derived through the LC_{50} method is available upon request of the TCEQ ecological risk assessors. Secondly, the workgroup selected the freshwater and marine water quality chronic values derived by the TCEQ (2003a, Water Quality Division) for wastewater permits and requests from the Office of Waste, based on the methodology defined in the TSWQS at 307.6(c)(7). As a third choice, the workgroup selected the Tier II secondary chronic values (SCVs) developed by Suter and Tsao (1996) of the Oak Ridge National Laboratory (ORNL). The Oak Ridge Tier II SCVs were derived for freshwater biota only. The last set of water quality benchmarks used are the U.S. EPA Region 4 Water Management Division chronic screening values (U.S. EPA Region 4, 2001). Both marine and freshwater values are provided.

The person may develop alternate benchmarks with appropriate justification (except where a state or federal criterion is indicated) as discussed previously and depicted in Figure 3-4. The values presented in Table 3-2 are preferred over alternate benchmarks.

3.5.4 Sediment Benchmarks

The benchmarks for sediment are intended to be protective of benthic biota, and are not necessarily protective of mammalian and avian receptors that may be exposed to COCs through the food chain or via the incidental ingestion of sediment. The preferred benchmarks are provided in Table 3-3. The following discussion briefly overviews the benchmark approaches that were selected by the multi-stakeholder ecological workgroup. More detail regarding these benchmarks, and others that were not selected as preferred benchmarks, is provided in Appendix A. Alternate sediment benchmarks, including those discussed in Appendix A, may be used with appropriate justification. The use of alternate benchmarks is discussed in Section 3.5.1.

For freshwater sediment benchmarks, the primary benchmarks selected were the Threshold Effect Concentrations (TECs) from MacDonald et al. (2000). Other data bases were used to expand the benchmark list. For antimony and silver, the Effects Range-Low (ER-L) values from Long and Morgan (1990), were used. The freshwater benchmarks for iron, manganese, several pesticides, and individual polychlorinated biphenyl (PCB) aroclors are Lowest Effects Levels

(LELs) as discussed in Persaud et al. (1993). For marine benchmarks, the primary benchmarks selected were the ER-L values in Long et al. (1995). The ER-L values for metals, PAHs, total DDTs, and total PCBs from this reference are provided in Table 3-3. The marine TELs from Smith et al. (1996b) for chlordane, lindane, dieldrin, and phthalates were also used. The Sum DDT, Sum DDE, and Sum DDE marine sediment benchmarks originate from Environment Canada (1997). Also, as was described in Section 3.5.1.2, an EqP process was used to derive freshwater and marine sediment benchmarks for VOCs.

Regarding PAHs, although benchmarks are provided for individual PAH compounds, low and high molecular weight (MW) PAHs (marine only), and total PAHs, the benchmarks for total PAHs are the most relevant for evaluating risk in an ERA. This is because PAHs almost always occur in the environment as mixtures. Values for individual and low and high MW PAHs are provided as guidelines to aid in the determination of disproportionate concentrations within the mixture that may be masked by the total. Therefore, PAHs may be screened out using the total PAH benchmark even if individual, low MW, or high MW PAH benchmarks are exceeded. However, any exceedances of individual, low MW, or high MW PAH secondary effect levels (see Table A-2 of Appendix A) may indicate adverse effects and therefore should be further discussed (e.g., in the uncertainty analysis). If appropriate, individual PAHs that exceed the secondary effect levels should be retained beyond the benchmark screening step (required element 1). The total PAH benchmarks are based on the thirteen parent PAH compounds listed in Table 3-3 (personal communication with Don MacDonald; October, 2003), meaning that if the person wishes to use a total PAH benchmark for screening, it is appropriate to have a value for all thirteen PAHs included in the sum. This is accomplished by using proxy values for the analyzed but undetected PAHs, and adding them to the concentrations of the detected PAHs for comparison to the total benchmark, assuming that the individual PAH has not been eliminated in accordance with the criteria at §350.71(k) of the TRRP rule. (A general discussion of proxy values is provided in §350.51(n) and appropriate methods for the determination of proxy values will be defined in the TRRP guidance titled *Determining Representative Concentrations* (RG-366/TRRP-15)). However, when significantly less than the thirteen parent PAHs are determined to be COCs, or if all of the thirteen parent PAHs are not included in the analyte list, screening must be based on individual PAH benchmarks.

At present, evaluating the impact of COCs associated with sediments is under widespread technical review. There is an ongoing technical debate about screening values and interpretation of sediment data. The sediment benchmarks presented in this guidance are based on current sources, and it is acknowledged that alternative sediment benchmarks may be justified. The existing derivation methods are based on correlations between the presence of COCs and observed sediment conditions. Developments are likely to aid in identification of causal relationships between sediment-associated COCs and impacts to biota. Consequently, improvements to recommended methods to derive sediment benchmarks may be discussed in future revisions of this guidance.

3.5.5 Soil Benchmarks

For the most part, the recommended soil benchmarks are terrestrial plant and earthworm

benchmark values from Efroymson et al. (1997 a and b). The soil benchmark values, and their respective test organism source (i.e., either plant, earthworm, or soil invertebrate) are provided in Table 3-4. In addition, the table lists the median Texas background concentration for most metals. If the concentration of a COC at an affected property is at or below the median Texas background or an approved site-specific background, the benchmark value may be ignored, even if the COC is bioaccumulative in soil (See §§350.51(l) and 350.71(k) for a discussion of background concentrations).

Currently, U.S. EPA has released a set of risk-based ecological soil screening levels (Eco-SSLs) that provide SSLs for plant or soil invertebrate endpoints for ten contaminants that are frequently of ecological concern (U.S. EPA, 2003 a,b and U.S. EPA, 2005 a - h). Three additional Eco-SSL documents have been issued that do not contain plant or soil invertebrate endpoints (i.e., chromium, vanadium and dieldrin). When an ECO-SSL is available for either plants or soil invertebrates, they have been incorporated into the soil benchmarks recommended in Table 3-4 (i.e., antimony, arsenic, barium, beryllium, cadmium, cobalt, lead, and pentachlorophenol; narrative statements are provided for aluminum and iron). The methodology used to develop Eco-SSLs has been revised as described in U.S. EPA, 2005i. This change in methodology resulted in updating some Eco-SSLs; these changes have been incorporated into Table 3-4.

The Eco-SSL derivation process represents the group effort of a multi-stakeholder workgroup consisting of federal, state, consulting, industry, and academic participants led by the U.S. Environmental Protection Agency Office of Superfund Remediation and Technology Innovation (OSRTI). U.S. EPA emphasizes that these Eco-SSLs are appropriate to all sites where certain soil parameters fall within a range of chemical and physical parameters. The Eco-SSLs for plants and soil invertebrates were derived to apply to soils where the pH is greater than or equal to 4.0 and less than or equal to 8.5, and the organic matter content is less than or equal to 10%. Based on these parameters, U.S. EPA emphasizes that in some situations, such as wetland soils that are regularly flooded (i.e., sediments), sewage sludge amended soils where the organic matter content is > 10%, and waste types where the pH is < 4.0, the Eco-SSLs do not apply.

U.S. EPA's process for developing Eco-SSLs is expected to continue, and more Eco-SSL documents are anticipated to be issued. As of this guidance update, Eco-SSLs are pending for copper, manganese, nickel, selenium, silver, zinc, DDT and metabolites, RDX, TNT and total PAHs. TCEQ will adopt these Eco-SSLs as soil benchmarks when they are released. In the event that any Eco-SSL documents are issued after the latest update to the TCEQ guidance, persons may propose to use the new Eco-SSL numbers as soil benchmarks. Some values for copper and zinc appearing in Table 3-4 were obtained from a 2000 draft effort from this workgroup (U.S. EPA, 2000). The Eco-SSL guidance documents, standard operating procedures, and background material are available through the following link: http://www.epa.gov/ecotox/ecossl/ .

CAS #	COC (mg/L)	Freshwater	Marine
Metals/Inorganics			
7429-90-5	Aluminum	0.087 [a]	

Table 3-2. Ecological Benchmarks for Water

CAS #	COC (mg/L)	Freshwater	Marine
7440-36-0	Antimony	0.160 [g]	
7440-38-2	Arsenic (d)	0.190 [c, w]	0.078 [c, w]
7440-39-3	Barium	16 [b]	25 [b]
7440-41-7	Beryllium	0.0053 [b]	
7440-42-8	Boron	0.0016 [e]	
7440-43-9	Cadmium (d)	0.0006 [c, f]	0.010 [c, w]
16887-00-6	Chloride	230 [a]	
7782-50-5	Chlorine	0.011 [a]	0.0075 [a]
18540-29-9	Chromium (Hex) (d)	0.0106 [c, w]	0.0496 [c, w]
16065-83-1	Chromium (Tri) (d)	0.1008 [c, f]	0.103 [g]
7440-48-4	Cobalt	1.5 [b]	
7440-50-8	Copper (d)	0.007 [c, h, w]	0.0036 [c, h, w]
57-12-5	Cyanide (free)	0.0107 [c, i]	0.0056 [c, i]
7439-89-6	Iron	1 [a]	
7439-92-1	Lead (d)	0.001 [c, f]	0.0053 [c, w]
7439-93-2	Lithium	0.014 [e]	
7439-95-4	Magnesium	3.23 [b]	
7439-96-5	Manganese	0.120 [e]	
7439-97-6	Mercury	0.0013 [c]	0.0011 [c]
7439-98--7	Molybdenum	2 [b]	
7440-02-0	Nickel (d)	0.0874 [c, f]	0.0131 [c, w]
7723-14-0	Phosphorus, Elemental		0.0001 [a]
7782-49-2	Selenium	0.005 [c]	0.136 [c]
7440-22-4	Silver (d, as free ion). See j for conversion.	0.00008 [c, k, w]	0.0002 [c, k, w]
7440-22-4	Silver (d)	0.0001 [a, f, k]	0.00019 [a, k]
7440-24-6	Strontium	1.5 [e]	
7783-06-4	Sulfide, hydrogen sulfide	0.002 [a]	0.002 [a]
7440-28-0	Thallium	0.004 [g]	0.0213 [g]
7440-31-5	Tin	0.073 [e]	
688-73-3	Tributyltin (TBT)	0.000024 [c]	0.000043 [c]
7440-61-1	Uranium (d)	0.700 [f, l]	
7440-62-2	Vanadium	0.020 [e]	
1314-62-1	Vanadium pentoxide	0.015 [b]	
7440-66-6	Zinc (d)	0.0581 [c, f]	0.0842 [c, w]
7440-67-7	Zirconium	0.017 [e]	

Table 3-2. Ecological Benchmarks for Water

CAS #	COC (mg/L)	Freshwater	Marine
Organochlorine Pesticides			
309-00-2	Aldrin	0.0003 [c, k]	0.00013 [c, k]
319-85-7	BHC (beta)	0.083 [b]	
319-84-6	BHC (alpha)	0.074 [b]	0.025 [b]
57-74-9	Chlordane	0.000004 [c]	0.000004 [c]
72-54-8	4,4' DDD	0.000011 [e]	0.000025 [g]
72-55-9	4,4'- DDE	0.0105 [g]	0.00014 [g]
50-29-3	4,4'- DDT	0.000001 [c]	0.000001 [c]
60-57-1	Dieldrin	0.000002 [c]	0.000002 [c]
959-98-8	Endosulfan I (alpha)	0.000056 [c]	0.000009 [c]
33213-65-9	Endosulfan II (beta)	0.000056 [c]	0.000009 [c]
1031-07-8	Endosulfan sulfate	0.000056 [c]	0.000009 [c]
115-29-7	Endosulfan (all isomers)	0.000051 [e, m]	
72-20-8	Endrin	0.000002 [c]	0.000002 [c]
7421-93-4	Endrin aldehyde	1.21 [b]	
76-44-8	Heptachlor	0.000004 [c]	0.000004 [c]
1024-57-3	Heptachlor epoxide	0.0000038 [a]	0.0000036 [a]
319-86-8	Delta Hexachlorocyclohexane (HCH)	0.141 [b]	
58-89-9	Hexachlorocyclohexane (Lindane)	0.00008 [c]	0.000016 [c, k]
77-47-4	Hexachlorocyclopentadiene	0.00007 [b]	0.00007 [g]
72-43-5	Methoxychlor	0.00003 [c]	0.00003 [c]
8001-35-2	Toxaphene	0.0000002 [c]	0.0000002 [c]
Other pesticides and PCBs			
107-02-8	Acrolein (acrylic aldehyde)	0.0014 [b]	0.005 [b]
63-25-2	Carbaryl (Sevin)	0.0002 [c, k]	0.0613 [c, k]
2921-88-2	Chloropyrifos (Dursban)	0.000041[c]	0.000006 [c]
333-41-5	Diazinon (Spectracide)	0.000043 [e, n]	
115-32-2	Dicofol (Kelthane)	0.0198 [c]	
330-54-1	Diuron	0.070 [c]	
86-50-0	Guthion (azinphos-methyl)	0.00001[c]	0.00001[c]
2691-41-0	HMX (Octogen)	0.150 [b]	
121-75-5	Malathion	0.00001[c]	0.00001[c]
2385-85-5	Mirex (dechlorane)	0.000001 [c]	0.000001 [c]
56-38-2	Parathion (ethyl)	0.000013 [c]	0.000178 [g]

Table 3-2. Ecological Benchmarks for Water

CAS #	COC (mg/L)	Freshwater	Marine
1336-36-3	Polychlorinated Biphenyls (PCB; Aroclors)	0.000014 [c]	0.00003 [c]
Polycyclic Aromatic Hydrocarbons (PAHs)			
83-32-9	Acenaphthene	0.023 [o]	0.0404 [o]
120-12-7	Anthracene	0.0003 [b]	0.00018 [b]
56-55-3	Benzo(a)anthracene	0.0346 [b]	
50-32-8	Benzo(a)pyrene	0.000014 [e]	
218-01-9	Chrysene	0.007 [b]	
53-70-3	dibenz[a,h]anthracene	0.005 [b]	
206-44-0	Fluoranthene	0.00616 [o]	0.00296 [o]
86-73-7	Fluorene	0.011 [b]	0.05 [b]
90-12-0	1-Methylnaphthalene	0.0021 [e]	
91-57-6	2-Methylnaphthalene	0.063 [b]	0.03 [b]
91-20-3	Naphthalene	0.25 [b]	0.125 [b]
85-01-8	Phenanthrene	0.030 [c]	0.0046 [c]
129-00-0	Pyrene	0.007 [b]	0.00024 [b]
Other Semi-Volatiles			
35572-78-2	2-amino-4,6-dinitrotoluene	0.74 [b]	
92-87-5	Benzidine	1.92 [b]	
65-85-0	Benzoic acid	9 [b]	
100-51-6	Benzyl alcohol	0.0086 [e]	
92-52-4	Biphenyl (diphenyl)	0.014 [e, m]	
111-44-4	Bis (2-Chloroethyl) Ether	12 [b]	
108-60-1	Bis (chloroisopropyl) ether	6.3 [b]	
117-81-7	Bis (2-ethyl-hexyl)phthalate	0.3 [a, r]	
117-84-0	Bis (n-octyl) phthalate	0.022 [b]	
101-55-3	4- Bromophenyl phenyl ether	0.0015 [e, m]	
85-68-7	Butylbenzyl phthalate	0.093 [b]	0.147 [b]
91-58-7	2- Chloronapthalene	0.054 [b]	
95-57-8	2- Chlorophenol	0.13 [b]	0.265 [b]
124-18-5	Decane	0.049 [e]	
8065-48-3	Demeton	0.0001 [c]	0.0001[c]
84-74-2	Di-n-butyl phthalate	0.007 [b]	0.005 [b]
132-64-9	Dibenzofuran	0.094 [b]	0.065 [b]
91-94-1	3,3- Dichlorobenzidine	0.053 [b]	0.037 [b]
120-83-2	2,4- Dichlorophenol	0.085 [b]	

Table 3-2. Ecological Benchmarks for Water

CAS #	COC (mg/L)	Freshwater	Marine
84-66-2	Diethyl phthalate	1.04 [b]	0.442 [b]
131-11-3	Dimethyl phthalate	0.330 [g]	0.580 [g]
105-67-9	2,4 - Dimethylphenol	0.105 [b]	
99-65-0	1,3- Dinitrobenzene	0.072 [b]	
51-28-5	2,4- Dinitrophenol	0.031 [b]	0.67 [b]
121-14-2	2,4- Dinitrotoluene	1.22 [b]	
122-66-7	1,2- Diphenylhydrazine	0.012 [b]	
27176-87-0	Dodecyl Benzenesulfonic Acid		0.058 [b]
78-59-1	Isophorone	6 [b]	0.65 [b]
1634-04-4	Methyl tert-butyl ether (MTBE)	11.07 [b]	
99-08-1	1- Methyl-3-nitrobenzene (3-Nitrotoluene)	0.375 [b]	
59-50-7	3- Methyl-4-Chlorophenol	0.0003 [g]	
534-52-1	2- Methyl-4,6-Dinitrophenol (dinitro-o-cresol)	0.012 [b]	
106-44-5	4- Methylphenol (p-cresol)	0.272 [b]	
95-48-7	2- Methylphenol (o-cresol)	0.56 [b]	0.51 [b]
86-30-6	N-Nitrosodiphenylamine	0.29 [b]	165 [b]
55-63-0	Nitroglycerin	0.069 [b]	
88-75-5	2- Nitrophenol	0.959 [b]	1.47 [b]
100-02-7	4- Nitrophenol	0.532 [b]	0.359 [b]
88-72-7	2- Nitrotoluene	0.44 [b]	
99-99-0	4- Nitrotoluene (1-methyl,4-nitrobenzene)	0.95 [b]	
62-75-9	N-nitrosodimethylamine	47 [b]	165 [b]
621-64-7	Nitrosodipropylamine	0.02 [b]	0.12 [b]
111-13-7	2- Octanone (methyl hexyl ketone)	0.0083 [e]	
608-93-5	Pentachlorobenzene	0.00047 [e, m]	0.129 [g]
87-86-5	Pentachlorophenol	0.0021 [c, p]	0.0096 [c]
78-11-5	PETN (Pentaerythrite-tetranitrate)	425 [b]	
108-95-2	Phenol	0.110 [n]	2.75 [b]
121-82-4	RDX (Cyclonite)	0.18 [b]	
95-94-3	1,2,4,5- Tetrachlorobenzene	0.05 [g]	0.129 [g]
95-95-4	2,4,5 Trichlorophenol	0.064 [c]	0.012 [c]
88-06-2	2,4,6 Trichlorophenol	0.0135 [b]	0.061 [b]
118-96-7	2,4,6 Trinitrotoluene (TNT)	0.050 [b]	0.050 [b]
Volatiles			
67-64-1	Acetone	101.2 [b]	282 [b]

Table 3-2. Ecological Benchmarks for Water

CAS #	COC (mg/L)	Freshwater	Marine
107-13-1	Acrylonitrile	0.076 [g]	0.291 [b]
71-43-2	Benzene	0.130 [e]	0.109 [g]
104-51-8	N-butylbenzene	0.036 [b]	
103-65-1	Propyl benzene	0.064 [b]	
135-98-8	sec-Butylbenzene	0.041 [b]	
98-06-6	tert-Butylbenzene	0.048 [b]	
75-27-4	Bromodichloromethane	2.16 [b]	
78-93-3	2-Butanone (MEK)	42.4 [b]	
75-15-0	Carbon disulfide	0.105 [b]	
56-23-5	Carbon tetrachloride (Tetrachloromethane)	0.0098 [e]	1.5 [g]
108-90-7	Chlorobenzene	0.064 [e]	0.105 [g]
124-48-1	Chlorodibromomethane	0.129 [b]	
67-66-3	Chloroform	0.89 [q]	4.1 [q]
74-87-3	Chloromethane	28 [b]	13.5 [b]
98-82-8	Cumene (isopropylbenzene)	0.255 [b]	
99-87-6	Cymene (4-isopropyltoluene)	0.042 [b]	
95-50-1	1,2- Dichlorobenzene	0.11 [b]	0.099 [b]
541-73-1	1,3- Dichlorobenzene	0.085 [b]	0.142 [b]
106-46-7	1,4- Dichlorobenzene	0.11 [b]	0.099 [b]
75-71-8	Dichlorodifluoromethane (Freon-12)	1.96 [b]	
75-34-3	1,1- Dichloroethane	2.57 [q]	
107-06-2	1,2 - Dichloroethane	6.3 [q]	5.65 [q]
75-35-4	1,1-Dichloroethene	1.5 [q]	12.5 [q]
540-59-0	1,2- Dichloroethene (mixed *cis* & *trans*	14 [q]	0.68 [q]
156-60-5	1,2 - Dichloroethene (*trans*)	22 [q]	
78-87-5	1,2- Dichloropropane	1.87 [b]	2.4 [g]
542-75-6	1,3- Dichloropropene	0.205 [b]	0.040 [b]
100-41-4	Ethyl Benzene	1.09 [b]	0.249 [b]
87-68-3	HCBD (Hexachlorobutadiene)	0.00093 [g]	0.00032 [g]
67-72-1	Hexachloroethane	0.012 [e, m]	0.0094 [g]
110-54-3	Hexane	0.00058 [e]	
591-78-6	2- Hexanone (methyl butyl ketone; MBK)	6.13 [b]	
108-10-1	4- Methyl-2-pentanone (MIBK)	26.4 [b]	61.5 [b]
74-83-9	Methyl Bromide (bromomethane)	0.11 [b]	0.6 [b]
593-74-8	Methyl Mercury (dimethylmercury)	0.0000028 [e]	

Table 3-2. Ecological Benchmarks for Water

CAS #	COC (mg/L)	Freshwater	Marine
80-62-6	Methyl methacrylate	11.6 [b]	
75-09-2	Methylene Chloride (dichloromethane)	11 [q]	5.42 [q]
98-95-3	Nitrobenzene	0.27 [g]	0.0668 [g]
71-41-0	1- Pentanol	0.110 [e]	
67-63-0	2- Propanol	0.0075 [e]	
100-42-5	Styrene (vinyl benzene)	1.25 [b]	0.455 [b]
79-34-5	1,1,2,2 - Tetrachloroethane	0.465 [b]	0.451 [b]
127-18-4	Tetrachloroethene	0.79 [q]	1.45 [q]
108-88-3	Toluene	1.45 [q]	0.48 [q]
75-25-2	Tribromomethane (bromoform)	0.149 [b]	1.22 [b]
120-82-1	1,2,4- Trichlorobenzene	0.051 [b]	0.022 [b]
71-55-6	1,1,1- Trichloroethane	2.45 [q]	1.56 [q]
79-00-5	1,1,2- Trichloroethane	0.90 [b]	0.275 [b]
79-01-6	Trichloroethene	0.55 [b]	0.97 [q]
75-69-4	Trichlorofluormethane (Freon-11)	0.871 [b]	
76-13-1	1,1,2-Trichlorotrifluorethane (Freon-113)	0.207 [b]	
95-63-6	1,2,4-Trimethylbenzene (Pseudocumene)	0.077 [b]	0.217 [b]
108-67-8	1,3,5-Trimethylbenzene (Mesitylene)	0.071 [b]	
108-05-4	Vinyl acetate	0.016 [e]	
75-01-4	Vinyl chloride (chloroethylene)	2.82 [b]	
108-38-3	m-Xylene	0.0018 [e, m]	
1330-20-7	Xylenes	1.34 [q]	0.85 [q]

a U.S. EPA, 2002.

b TCEQ 2003a. In-house water quality chronic values derived for wastewater permits and requests from the Office of Waste based on LC_{50} values in accordance with methodology defined in the TSWQS. Water Quality Division.

c Texas Surface Water Quality Standards Chronic (unless otherwise noted) Criteria (30 TAC §307.6, Table 1, Effective August 17, 2000).

d Indicates that the criteria for a specific parameter are for the dissolved portion in water.

e Tier II Secondary Chronic Values from Suter and Tsao (1996).

f Criteria calculated using a hardness value of 50 mg/L. See formula for standard that follows.

Table 3-2. Ecological Benchmarks for Water

g U.S. EPA Region 4. 2001. Value derived from Region 4 Water Quality Management Division screening worksheet.

h In designated oyster waters an acute saltwater copper criterion of 3.6 micrograms per liter applies outside of the mixing zone of permitted discharges, and specified mixing zones for copper will not encompass oyster reefs containing live oysters.

i Compliance will be determined using the analytical method for cyanide amenable to chlorination or by weak acid dissociable cyanide.

j Based on the procedure defined in TCEQ (2003), the percent dissolved silver that is in the free ionic form is estimated from the following regression equation:

$$Y = \exp [\exp (1/ (0.6559 + 0.0044(Cl)))]$$

where, Y = % of dissolved silver that is in free ionic form, and Cl = dissolved chloride concentration (mg/l). Persons should use the 50th percentile chloride value (from TCEQ, 2003) for the nearest downstream segment unless site-specific data is available. Because there is no readily available means to predict the percent free ion in marine waters, silver should be evaluated as dissolved silver alone.

k There is only an acute criterion (no chronic criterion). The indicated value is the acute criterion divided by 10.

l State of Colorado hardness-based water quality standard (Colorado Department of Public Health and Environment, 2005).

m Values calculated for OSWER 1996 as provided in Suter and Tsao (1996).

n Value calculated using Great Lakes Water Quality Initiative Tier I methodology (U.S. EPA, 1993a) as provided in Suter and Tsao (1996).

o These numbers are FCVs calculated by the EPA for use in the derivation of the sediment quality criteria (U.S. EPA, 1993b, c).

p Criteria calculated using a pH of 6.0. See formula for standard that follows.

q Value derived by work group using the LC_{50} approach discussed in Section 3.5.1.1. Contact the TCEQ Technical Support Section (Remediation Division) for a full discussion of each value.

r According to U.S. EPA, 2002, bis(2-ethylhexyl)phthalate is not toxic to aquatic organisms at or below its solubility limit. Benchmark set at solubility limit given at TRRP Figure 30 TAC §350.73 (e).

w Indicates that the criterion is multiplied by a water-effects ratio in order to incorporate the effects of local water chemistry on toxicity. The water-effects ratio is equal to 1 except where sufficient data is available to establish a site-specific, water-effects ratio. Water-effects ratios for individual

Table 3-2. Ecological Benchmarks for Water

water bodies are listed in Appendix E of the TSWQS. The number preceding the “w” in the freshwater criterion equation is a U.S. EPA conversion factor.

Cadmium - $0.909we^{(0.7852(\ln(hardness))-3.490)}$	Chromium (Tri) - $0.860we^{(0.8190(\ln(hardness))+1.561)}$
Copper - $0.960we^{(0.8545(\ln(hardness))-1.386)}$	Lead - $0.729we^{(1.273(\ln(hardness))-4.705)}$
Nickel - $0.997we^{(0.8460(\ln(hardness))+1.1645)}$	Pentachlorophenol - $e^{(1.005(pH)-5.290)}$
Zinc - $0.986we^{(0.8473(\ln(hardness))+0.7614)}$	Uranium - $e^{(1.1021(\ln(hardness))+2.2382)}$
Silver - $(0.85)e^{(1.72(\ln(hardness))-6.59)}$	

Table 3-2. Ecological Benchmarks for Water

References Cited for Table 3-2

Colorado Department of Public Health and Environment (CDPHE). 2005. Water Quality Control Commission Regulation No. 31. The Basic Standards and Methodologies for Surface Water (5 CCR 1002-31). Amended November 8, 2004 and effective March 22, 2005.

OSWER (Office of Solid Waste and Emergency Response). 1996. Ecotox Thresholds. ECOLOGICAL Update 3 (2):1-12.

Suter, G.W., and C.L. Tsao. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. Lockheed Martin Energy Systems, Inc. ES/ER/TM-96/R2.

TCEQ. 2003. Procedures to Implement the Texas Surface Water Quality Standards. Water Quality Division. RG-194 (revised). January, 2003. http://www.tceq.state.tx.us/permitting/water_quality/wq_assessment/standards/WQ_standards_implementing.html

U.S. EPA. 1993a. Great Lakes Water Quality Initiative Criteria documents for the protection of aquatic life in ambient water (February 1993 Draft). PB93-154656. National Technical Information Service. Springfield, VA.

U.S. EPA. 1993b. Sediment quality criteria for the protection of benthic organisms - acenaphthene. EPA-822-R-93-013. U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA. 1993c. Sediment quality criteria for the protection of benthic organisms - fluoranthene. EPA-822-R-93-012. U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA. 2002. National Recommended Water Quality Criteria: 2002. Office of Water. EPA 822-R-02-047. November.

U.S. EPA Region 4. 2001. Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment. Originally published November 1995. Website version last updated November 30, 2001: http://www.epa.gov/region4/waste/ots/ecolbul.htm

Table 3-3. Ecological Benchmarks for Sediment

CAS #	COC (mg/kg dry wt.)	Freshwater	Marine
Inorganics			
7440-36-0	Antimony	2 [a]	
7440-38-2	Arsenic	9.79	8.2
7440-43-9	Cadmium	0.99	1.2
7440-47-3	Chromium	43.4	81
7440-48-4	Cobalt	50 [b]	
7440-50-8	Copper	31.6	34
7439-89-6	Iron	20,000 [b]	
7439-92-1	Lead	35.8	46.7
7439-96-5	Manganese	460 [b]	
7439-97-6	Mercury	0.18	0.15
7440-02-0	Nickel	22.7	20.9
7440-22-4	Silver	1 [a]	1
7440-66-6	Zinc	121	150
Polycyclic Aromatic Hydrocarbons (PAHs) *Footnote (i) applies to all listed PAHs*			
83-32-9	Acenaphthene	0.0067 [j]	0.016
208-96-8	Acenaphthylene	0.0059 [j]	0.044
120-12-7	Anthracene	0.0572	0.0853
56-55-3	Benz(a)anthracene	0.108	0.261
50-32-8	Benzo(a)pyrene	0.150	0.43
218-01-9	Chrysene	0.166	0.384
53-70-3	Dibenz(a,h)anthracene	0.033	0.0634
206-44-0	Fluoranthene	0.423	0.6
86-73-7	Fluorene	0.0774	0.019
91-57-6	2- Methyl naphthalene		0.070
91-20-3	Naphthalene	0.176	0.160
85-01-8	Phenanthrene	0.204	0.24
129-00-0	Pyrene	0.195	0.665
	Low Molecular Weight PAHs		0.552 [e, f]
	High Molecular Weight PAHs		1.7 [e, g]
	Total PAHs	1.61[e, h, i]	4.022 [e, h, i]
Chlorinated Pesticides/PCBs/Benzenes			
309-00-2	Aldrin	0.002 [b]	
27323-18-8	Aroclor 1254	0.060 [b]	

Table 3-3. Ecological Benchmarks for Sediment

CAS #	COC (mg/kg dry wt.)	Freshwater	Marine
12674-11-2	Aroclor 1016	0.007 [b]	
11096-82-5	Aroclor 1260	0.005 [b]	
12672-29-6	Aroclor 1248	0.030 [b]	
319-84-6	alpha-BHC	0.006 [b]	
319-85-7	beta-BHC	0.005 [b]	
58-89-9	gamma-BHC (Lindane)	0.00237	0.00032 [d]
608-73-1	BHC	0.003 [b, e]	
57-74-9	Chlordane (Total)	0.00324	0.00226 [d]
60-57-1	Dieldrin	0.0019	0.000715 [d]
72-20-8	Endrin	0.00222	
118-74-1	HCB (Hexachlorobenzene)	0.020 [b]	
1024-57-3	Heptachlor epoxide	0.00247	
2385-85-5	Mirex	0.007 [b]	
72-55-9	Sum DDE	0.00316 [e]	0.00207 [e]
72-54-8	Sum DDD	0.00488 [e]	0.00122 [e]
50-29-3	Sum DDT	0.00416 [e]	0.00119 [e]
	Total DDT	0.00528 [e]	0.00158 [e]
1336-36-3	Total PCBs	0.0598 [e]	0.0227 [e]
Organophosphate Pesticides			
2642-71-9	Azinphos-ethyl	0.000018 [l]	
86-50-0	Azinphos-methyl (Guthion)	0.000062 [l]	
331-41-5	Diazinon	0.00038 [l]	
121-75-5	Malathion	0.00067 [m]	
	Phoxim	0.000060 [l]	
	Pyrazophos	0.000015 [l]	
Other Pesticides			
8001-35-2	Toxaphene	0.00010 [k]	
1912-24-9	Atrazine	0.00030 [l]	
122-34-9	Simazine	0.00034 [l]	
Phthalates			
117-81-7	Bis(2-ethyl-hexyl)phthalate	0.182 [d]	0.182 [d]
84-66-2	Diethyl phthalate	0.630 [m]	

Table 3-3. Ecological Benchmarks for Sediment

CAS #	COC (mg/kg dry wt.)	Freshwater	Marine
Volatiles *Footnote (n) applies to all listed volatiles, unless otherwise noted*			
67-64-1	Acetone	60.03	167.23
107-13-1	Acrylonitrile	0.05	0.17
71-43-2	Benzene	0.16	0.14
104-51-8	N-butylbenzene	1.09	
103-65-1	Propyl benzene	0.72	
135-98-8	Sec-butylbenzene	0.88	
98-06-6	Tert-butylbenzene	1.21	
75-27-4	Bromodichloromethane	2.46	
78-93-3	2-butanone	25.71	
75-15-0	Carbon disulfide	0.12	
56-23-5	Carbon tetrachloride	0.02	3.67
108-90-7	Chlorobenzene	0.17	0.29
124-48-1	Chlorodibromomethane	0.16	
67-66-3	Chloroform (trichloromethane)	0.94	4.30
74-87-3	Chloromethane	17.80	8.74
98-82-8	Cumen	8.99	
99-87-6	p-Cymene	1.00	
95-50-1	1,2-dichlorobenzene	0.83	0.74
541-73-1	1,3-dichlorobenzene	0.19	0.32
106-46-7	1,4-dichlorobenzene	0.77	0.70
75-71-8	Dichlorodifluoromethane	3.68	
75-34-3	1,1-dichloroethane	2.32	
107-06-2	1,2-dichloroethane	4.79	4.30
75-35-4	1,1-dichloroethene	1.87	15.41
156-60-5	1,2-dichloroethene (trans)	23.95	
78-87-5	1,2-dichloropropane	2.20	2.82
542-75-6	1,3-dichloropropene	0.23	0.04
100-41-4	Ethylbenzene	2.86	0.65
87-68-3	HCBD (Hexachlorobutadiene)	0.055 [k]	0.02
67-72-1	Hexachloroethane	0.23	0.18
110-54-3	Hexane, n-	0.0031	
591-78-6	2-hexanone	4.70	

Table 3-3. Ecological Benchmarks for Sediment

CAS #	COC (mg/kg dry wt.)	Freshwater	Marine
108-10-1	4-methyl-2-pentanone (MIBK)	19.43	45.34
74-83-9	Methyl bromide	0.08	0.42
22967-92-6	Methyl Mercury	0.0000017	
80-62-6	Methyl methacrylate	9.50	
75-09-2	Methylene chloride	7.75	3.82
98-95-3	Nitrobenzene	0.51	0.13
71-41-0	1-Pentanol	0.07	
67-63-0	2-Propanol	0.0047	
100-42-5	Styrene	10.24	3.72
79-34-5	1,1,2,2-tetrachloroethane	0.63	0.61
127-18-4	Tetrachloroethene	1.69	3.10
108-88-3	Toluene	2.88	0.94
75-25-2	Bromoform	0.22	1.78
120-82-1	1,2,4-trichlorobenzene	0.88	0.39
71-55-6	1,1,1-trichloroethane	4.13	2.63
79-00-5	1,1,2-trichloroethane	0.98	0.30
79-01-6	Trichloroethene	0.84	1.47
75-69-4	Trichlorofloromethane	1.69	
76-13-1	1,1,2-trichlorotrifluoroethane	2.78	
95-63-6	1,2,4-trimethylbenzene	0.76	2.16
108-67-8	1,3,5-trimethylbenzene	0.77	
108-05-4	Vinyl acetate	0.010	
75-01-4	Vinyl chloride	1.96	
108-38-3	m-Xylene	0.0046	
1330-20-7	Xylenes	4.00	2.54

Freshwater - Unless otherwise noted, benchmarks are Threshold Effect Concentration (TEC) from: MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31.

Marine - Unless otherwise noted, benchmarks are Effects Range Low (ERL) from: Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environ. Manage. 19(1):81-97.

Table 3-3. Ecological Benchmarks for Sediment

a Effects Range Low (ERL) from: Long, E.R. and L.G. Morgan. 1990. The Potential for Biological Effects of Sediment-sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52, March 1990.

b Lowest Effects Level (LEL) from: Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Water Resources Branch. Ontario Ministry of the Environment and Energy. August.

c No "c" footnotes.

d Threshold Effects Level (TEL) from: Smith, S.L., D.D. MacDonald, K.A. Keenleyside, and C.L. Gaudet. 1996b. The Development and Implementation of Canadian Sediment Quality Guidelines. In: Development and Progress in Sediment Quality Assessment: Rationale, Challenges, Techniques & Strategies. Ecovision World Monograph Series. Munawar & Dave (Eds.). Academic Publishing, Amsterdam, The Netherlands.

e When benchmarks represent the sum of individual compounds, isomers, or groups of congeners, and the chemical analysis indicates an undetected value, the proxy value specified at §350.51 (n) shall be used for calculating the sum of the respective compounds, isomers, or congeners. This assumes that the particular COC has not been eliminated in accordance with the criteria at §350.71 (k).

f The low molecular weight PAH benchmark is to be compared to the sum of the concentrations of the following compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, and 2-methyl napthalene. The PAH benchmark is not the sum of the corresponding benchmarks listed for the individual compounds.

g The high molecular weight PAH benchmark is to be compared to the sum of the concentrations of the following compounds: fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene, and dibenzo [a,h]anthracene. The PAH benchmark is not the sum of the corresponding benchmarks listed for the individual compounds.

h Total PAH refers to the sum of the concentrations of each of low and high molecular weight PAHs listed above and any other PAH compounds that are not eliminated in accordance with §350.71 (k).

i The benchmarks for total PAHs are the most relevant in evaluating risk in an ERA as PAHs almost always occur as mixtures. Values for individual, low molecular weight, and high molecular weight PAHs are provided as guidelines to aid in the determination of disproportionate concentrations within the mixture that may be masked by the total. See discussion in Section 3.5.4.

j CCME (Canadian Council of Ministers of the Environment). 1999. Canadian environmental quality guidelines. Winnipeg, Manitoba.

k NYSDEC (New York State Department of Environmental Conservation). 1999. Technical

Table 3-3. Ecological Benchmarks for Sediment

guidance for screening contaminated sediments. Division of Fish , Wildlife, and Marine Resources. Albany, New York. 36 pp.

l Stortelder, P.B., M.A. Vandergaag, and L.A. van der Kooij. 1989. Perspectives for water organisms. An ecotoxicological basis for quality objectives for water and sediment. Part1. Results and calculations. DBW/RIZA Memorandum N. 89.016a. (English Version August, 1991). Institute for Inland Water Management and Waste Water Treatment. Lelystad, Netherlands.

m U.S. EPA. 1997. The incidence and severity of sediment contamination in surface waters of the United States. Volume 1: National sediment quality survey. EPA 823-R-97-006. Office of Science and Technology (4305). Washington, District of Columbia.

n Benchmarks derived using formula in: Fuchsman, P.C. 2003. Modification of the Equilibrium Partitioning Approach for Volatile Organic Compounds in Sediment. Environ Toxicol Chem. 22:1532-1534. TCEQ Surface water values from Table 3-2 were used for water quality values. TRRP-24 default values of 1% fraction organic carbon (f_{oc}) and 0.37 porosity were used. The person should adjust these values if sufficient site-specific data indicate they are not representative.

Table 3-4. Ecological Benchmarks for Soil

CAS #	COC (mg/kg dry wt.)	Earth-worms [a]	Plants [b]	Median Background [c]
Metals/Inorganics				
7429-90-5	Aluminum [d]			30,000
7440-36-0	Antimony	78 [e, f]	5	1
7440-38-2	Arsenic	60	18 [m]	5.9
7440-39-3	Barium	330 [f, h]	500	300
7440-41-7	Beryllium	40 [f, i]	10	1.5
7440-42-8	Boron		0.5	30
7726-95-6	Bromine		10	
7440-43-9	Cadmium	140 [f, j]	32 [j]	
7440-47-3	Chromium	0.4	1	30
7440-48-4	Cobalt		13 [k]	7
7440-50-8	Copper	61 [f, g]	100	15
7782-41-4	Fluorine		200	190
7553-56-2	Iodine		4	
7439-89-6	Iron [l]			15,000
7439-92-1	Lead	1700 [n]	120 [f, n]	15
7439-93-2	Lithium		2	
7439-96-5	Manganese		500	300
7439-97-6	Mercury	0.1	0.3	0.04
7439-98-7	Molybdenum		2	
7440-02-0	Nickel	200	30	10
7782-49-2	Selenium	70	1	0.3
7440-22-4	Silver		2	
7440-24-6	Strontium			100
7440-26-8	Technetium		0.2	
7440-28-0	Thallium		1	0.7
7440-29-1	Thorium			9.3
7440-31-5	Tin		50	0.9
7440-32-6	Titanium			2,000
7440-61-1	Uranium		5	
7440-62-2	Vanadium		2	50
7440-66-6	Zinc	120 [f, g]	190 [g]	30

Table 3-4. Ecological Benchmarks for Soil

CAS #	COC (mg/kg dry wt.)	Earth-worms [a]	Plants [b]	Median Background [c]
Polycyclic Aromatic Hydrocarbons (PAHs)				
83-32-9	Acenaphthene		20	
86-73-7	Fluorene	30		
Semi-Volatiles				
92-52-4	Biphenyl (diphenyl)		60	
108-43-0	3-chlorophenol	10	7	
106-46-7	1,4-Dichlorobenzene	20		
95-77-2	3,4-dichlorophenol	20	20	
84-74-2	Di-n-butyl phthalate		200	
84-66-2	Diethyl phthalate		100	
131-11-3	Dimethylphthalate	200		
51-28-5	2,4-dinitrophenol		20	
100-02-7	4-Nitrophenol	7		
86-30-6	N-Nitrosodiphenylamine	20		
527-20-8	Pentachloroaniline	100		
608-93-5	Pentachlorobenzene	20		
87-86-5	Pentachlorophenol	31 [f, o]	5 [o]	
108-95-2	Phenol	30	70	
634-66-2	1,2,3,4-Tetrachlorobenzene	10		
4901-51-3	2,3,4,5- Tetrachlorophenol	20		
95-95-4	2,4,5- Trichlorophenol	9	4	
88-06-2	2,4,6- Trichlorophenol	10		
Volatiles				
108-90-7	Chlorobenzene	40		
78-87-5	1,2-Dichloropropane	700		
98-95-3	Nitrobenzene	40		
100-42-5	Styrene		300	
108-88-3	Toluene		200	
87-61-6	1,2,3-Trichlorobenzene	20		
120-82-1	1,2,4-Trichlorobenzene	20		

Table 3-4. Ecological Benchmarks for Soil

CAS #	COC (mg/kg dry wt.)	Earth-worms [a]	Plants [b]	Median Background [c]
Other Organics/PCBs/Pesticides				
1336-36-3	Polychlorinated Biphenyls		40	
108-42-9	3-chloroaniline	30	20	
554-00-7	2,4-dichloroaniline	100		
95-76-1	3,4-dichloroaniline	20		
77-47-4	Hexachlorocyclopentadiene		10	
636-30-6	2,4,5-Trichloroaniline	20	20	
3481--20-7	2,3,5,6-Tetrachloroaniline	20	20	
79-07-2	Chloroacetamide	2		
110-00-9	Furan		600	

a Efroymson, R.A., M.E. Will, and G.W. Suter. 1997. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision. Lockheed Martin Energy Systems, Inc. ES/ER/TM-126/R2.

b Efroymson, R.A., M.E. Will, G.W. Suter, and A.C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Lockheed Martin Energy Systems, Inc. ES/ER/TM-85/R3.

c Texas-Specific Median Background Concentration (Figure 30 TAC §350.51(m)).

d Potential ecological risks associated with aluminum in soils is identified based on the measured soil pH. Where aluminum is a COC, it should only be retained for those soils with a soil pH less than 5.5. Source: U.S. Environmental Protection Agency. Ecological Soil Screening Level for Aluminum. Interim Final. OSWER Directive 9285.7-60. November 2003.

e U.S. EPA. Ecological Soil Screening Level for Antimony. Interim Final. OSWER Directive 9285.7-61. February 2005.

f Screening values for soil invertebrates.

g U.S. EPA. 2000. Ecological Soil Screening Level Guidance. Draft. Office of Emergency and Remedial Response. July 10, 2000.

h U.S. EPA. Ecological Soil Screening Levels for Barium. Interim Final. OSWER Directive 9285.7-63. February 2005.

Table 3-4. Ecological Benchmarks for Soil

i U.S. EPA. Ecological Soil Screening Levels for Beryllium. Interim Final. OSWER Directive 9285.7-64. February 2005.

j U.S. EPA. Ecological Soil Screening Levels for Cadmium. Interim Final. OSWER Directive 9285.7-65. March 2005.

k U.S. EPA. Ecological Soil Screening Levels for Cobalt. Interim Final. OSWER Directive 9285.7-67. March 2005.

l Iron is not expected to be toxic to plants in well-aerated soils between pH 5 and 8. Iron's relative importance is not so much based on its direct chemical toxicity, but its effect as a mediator in the geochemistry of other potentially toxic metals and the potential hazard of depositing flocculent. Source: U.S. Environmental Protection Agency. Ecological Soil Screening Level for Iron. Interim Final. OSWER Directive 9285.7-69. November 2003.

m U.S. EPA. Ecological Soil Screening Levels for Arsenic. Interim Final. OSWER Directive 9285.7-62. March 2005.

n U.S. EPA. Ecological Soil Screening Levels for Lead. Interim Final. OSWER Directive 9285.7-70. March 2005.

o U.S. EPA. Ecological Soil Screening Levels for Pentachlorophenol. Interim Final. OSWER Directive 9285.7-58. March 2005.

3.6 Communities, Feeding Guilds, and Representative Species

3.6.1 Communities

Ecological communities are a collection of plant and animal populations occupying the same habitat in which the various species interact with one another. However, for purposes of this guidance, "communities" will mostly refer to those groups whose exposure to COCs can be evaluated in terms of the media in which they reside. These communities consist of soil invertebrates, terrestrial vegetation, benthic invertebrates, water column invertebrates, algae, and rooted aquatic vegetation. COCs that exceed ecological (community-level) benchmarks but that do not subsequently prove to be a risk to higher trophic level receptors may still impact these community-level receptors. Depending on the site-specific circumstances, the person may be required to demonstrate that impacts to these communities will not result in unacceptable (i.e., nontoxic) consequences for the more mobile or wide-ranging receptors. Generally, it is not anticipated that exceedances of benchmarks will result in the development of COC-specific PCLs for communities, with the exception of benthic invertebrates as discussed below.

By definition, ecological PCLs are primarily intended to be protective for more mobile or wide-ranging ecological receptors and, where appropriate, benthic invertebrate communities within waters in the state. Although benthic invertebrates play a very important role by functioning at the bottom of the aquatic food chain and serving as a critical pathway for the transfer of energy and nutrients to higher trophic level organisms, the commission recognizes that the benthic community in some water bodies may be diminished for reasons unrelated to releases of COCs from property subject to the TRRP regulation. The bullets below provide some guidance as to where the commission believes it to be unnecessary to determine an ecological PCL for sediment that is protective of the benthic invertebrate community. This does not preclude an evaluation of risks to higher level trophic level organisms that may forage in these types of water bodies or nearby water bodies (that could become impacted as a result of sediment COC transport). Nor does this preclude the TCEQ from requiring additional evaluations at these types of locations on a case-by-case basis where significant exposure conditions warrant (e.g., acutely toxic concentrations, presence of free product).

- Routinely dredged water bodies. This includes the portion of the channel that is actually dredged at a frequency of every three years or less. Risks to benthic communities that are potentially exposed to COCs in the sediments that are not routinely dredged (such as significant areas of shallow waters near the banks that are not used for shipping traffic), should be evaluated where the exposure pathway is complete (see discussion below).

- Intermittent streams (dries up completely at least one week a year) without perennial pools. (Intermittent streams with perennial pools are defined at §307.3 (a), as amended and discussed in the Implementation Procedures (TCEQ, 2003), as amended.)

- Water bodies with concrete-lined channels (bottom and sides).

- Segments 1006 and 1007 of the Houston Ship Channel as defined at §307.10, Appendix C, as amended, excluding tidal tributaries to these segments.

- Classified and unclassified water bodies with a designation of no aquatic life use, as indicated in §307.10, Appendices A and D, as amended.

Benthic recovery in dredged areas is quite rapid, taking from a few months to a year (Swartz et al., 1980 and Van Dolah et al., 1984). Hence, three years was selected as a conservative estimate of benthic recovery. For federal projects, the U.S. Army Corps of Engineers district offices can be contacted to determine the frequency of dredging for a given reach of a water body. Where appropriate, the person should evaluate the possibility of COC transport and potential impact to benthic communities downstream or down gradient of the types of water bodies indicated above. For water bodies that are not discussed above, or if it is known and documented that a particular water body is scheduled to be dredged within three years of APAR submittal, the person may evaluate the suitability of a sediment PCL protective of benthic invertebrates as part of the uncertainty analysis discussed in Section 3.12 pursuant to §350.77(c)(8). This would only be required for sediment COCs that have not been eliminated from a Tier 2 SLERA in accordance with §350.77(c)(1)-(7).

3.13 PCL Calculation

3.13.2 Selection of Comparative and Final Ecological PCLs

§350.77(c)(9) requires the person to develop medium-specific PCLs bounded by the NOAEL and the LOAEL prior to selection of a final PCL. These PCLs, referred to here as "comparative PCLs", are developed for each remaining COC associated with each relevant measurement receptor for a medium and, where appropriate, for the medium itself in the case of benthic invertebrates. The final ecological PCL[2] for a COC in a particular medium should be the lowest of the comparative PCLs and, except as discussed below, should lie between values bounded by the NOAEL and the LOAEL for the most susceptible measurement receptor/community. The reason for this is that the ERA process has been designed to allow the use of every realistic exposure assumption (and any site-specific data) before PCLs are developed. When these realistic exposure assumptions are incorporated into the analysis, TCEQ can be reasonably assured that any COC having a LOAEL HQ ≥ 1 resulting from the exercise in required element (7) has the potential to pose unacceptable ecological risk. This also means that remediation to a LOAEL-based PCL derived from realistic exposure assumptions may result in unacceptable ecological risk still remaining within that specific medium. As discussed below (see #5), the foundation for selecting a comparative PCL that is skewed toward either the NOAEL-based or LOAEL-based PCL should be made in the uncertainty analysis.

The TRRP rule is intentionally silent on how to select a comparative ecological PCL that is bounded by the NOAEL and LOAEL to allow the person the flexibility of making this determination. However, TCEQ has developed some guidelines to assist in this determination, although these may vary depending upon site-specific circumstances. Generally speaking, when trying to establish comparative ecological PCLs for the relevant measurement receptors, it is recommended that the following guidelines be used:

1) With the exception of the benthic PCL (see #6), as a default, the average between the NOAEL-based and LOAEL-based PCLs for a COC in a specific medium can be used as the comparative PCL, provided that the NOAEL and LOAEL do not differ more than a factor of ten. For example, if the NOAEL-based PCL for a COC for a measurement receptor was determined to be 12 mg/kg and the LOAEL-based PCL was 60 mg/kg, then the average (i.e., comparative PCL) would be $(12 + 60) \div 2 = 36$ mg/kg. Selection of this average value does not require any further justification, merely a statement identifying the comparative PCL as the average of the NOAEL-based and LOAEL-based PCLs.

2) One exception to having the comparative PCL lie between the upper and lower bounds occurs

[2]The final ecological PCL should not be confused with the critical PCL. The critical PCL is the lower of the human health PCL and the final ecological PCL for a particular COC within a specific medium. See additional discussion of the critical PCL in Section 5.2 and in the TRRP guidance *Critical PCLs* (RG-366/TRRP-25).

whenever a threatened/endangered species is at risk. In this case, the NOAEL-based PCL should be used as the comparative PCL because TCEQ will not advocate remediation to a concentration level (i.e., > NOAEL-based PCL) that is likely to cause any adverse effect to individual receptors of a threatened/endangered species.

3) Another exception to having the comparative PCL lie between the upper and lower bounds may occur in situations where only conservative exposure assumptions are used. As this is somewhat contrary to required element (7) in the TRRP rule where the person is instructed to justify the use of less conservative exposure assumptions, this situation is not expected to occur often. However, if costs, technical impracticability, or other reasons prevent either the collection or the utilization of data to support the use of less conservative exposure assumptions, the LOAEL-based PCL could be used as the comparative PCL. In addition, there may be other scenarios that warrant the consideration of using the LOAEL-based PCL, but these will need to be examined on a case-by-case basis.

4) If a mixture of conservative and justified less conservative assumptions is used, the person could either select the average value as discussed in #1 or a value that is biased toward the LOAEL bound. The degree of bias should be commensurate with the measure of conservatism remaining in the exposure assumption. For example, if at an affected property consisting of two acres, less conservative exposure assumptions were justified for a measurement receptor that was believed to be wide-ranging but whose exact range was unknown and therefore an area use factor of 1 was used, then a bias toward the LOAEL bound (e.g., 75% of the LOAEL-based PCL) could be appropriate. As usual, the selected value would depend on site-specific circumstances.

5) Although the uncertainty analysis precedes the development of PCLs, the person should discuss there any remaining conservative or non-conservative practices within the refined exposure analysis or any other circumstances that would ultimately influence the selection of a comparative PCL that was biased toward the LOAEL or NOAEL bound. Presumably, the person has carefully considered and has already chosen the most relevant NOAELs and LOAELs (see Section 3.10). There are, however, times when a discussion of this TRV uncertainty can be used to aid in the determination of the comparative PCL. For example, if the most relevant (or only) TRV for a COC is derived from a particularly toxic form of that COC and there is no reason to believe that the more toxic form is present or can be developed through natural processes (e.g., methylation) at the affected property, then the bias could be toward the LOAEL bound (e.g., 90% of the LOAEL-based PCL), as to do otherwise would be overly conservative.[3] Bias toward the NOAEL bound (e.g., 75% of the average) could be justifiable whenever a complete ecological exposure pathway was not accounted for in the exposure analysis because of a lack of toxicological data (see the example of the volatile COC and inhalation pathway discussed in Section 3.12).

[3]The use of this guideline requires that the person provides - in the uncertainty analysis - a convincing discussion that the more toxic form of the COC is not present and likely could not develop at the affected property. Ideally, this discussion should be based on sampling and analysis data.

6) A benthic invertebrate community potentially impacted by COC releases from an affected property may require the development of a PCL. This PCL could be for the COC-laden groundwater that is discharging to the sediments or it may be for the sediment itself. It has been previously stated that TCEQ does not advocate using the benchmark values in Tables 3-2 through 3-4 as cleanup goals because of their fairly conservative nature. However, as presented in Appendix A, for the sediment benchmarks (Table 3-3) there is usually available a corresponding second level of effects value from the same database (see Table A-2). For example, among the primary benchmarks used for freshwater sediment were the Threshold Effect Concentrations (TECs) provided in MacDonald et al. (2000). The second effect levels from this same database are called probable effect concentrations (PECs). The TEC was intended to estimate the concentration for a given COC below which adverse biological affects only rarely occurred. The PEC was intended to represent the concentration for a given COC above which adverse biological affects frequently occurred.

For the development of benthic PCLs, it is recommended that the person view the primary sediment benchmarks in Table 3-3 as NOAELs and examine Table A-2 for the second effect levels and view those values as LOAELs. In developing the benthic PCL, the same logic presented in the preceding guidelines should be applied, with one notable exception. The midpoint may continue to be proposed by the person as the comparative PCL without further justification, but it will not be considered a default when there is a weight-of-evidence that suggests the midpoint value is not protective of the benthic community (also see the discussion of EqP-derived benchmarks in Section 3.5.1.2 and Appendix A). For instance, the TEC for copper in freshwater is 31.6 mg/kg and the PEC is 149 mg/kg. The average that may be proposed as the comparative PCL would be $(31.6 + 149) \div 2 = 90.3$ mg/kg. However, if there are reliable and/or more relevant (e.g., local) studies from the literature indicating that values above 80 mg/kg have been shown to cause unacceptable levels of impact to the benthic community, then the midpoint value of 90.3 mg/kg may be questioned.

Alternatively, the person may evaluate the individual studies that comprise the effects-level databases, find the most applicable study, and recommend a PCL that is believed to be more suited to the actual circumstances (e.g., affected species, sediment composition) of the person's affected property. Of course, such a recommendation will need to be adequately justified and accompanied with supporting documentation.

Finally, the person may also choose to utilize an EqP method for developing a benthic PCL. The basic theory behind this approach was presented in Section 3.5.1.2. Based on the inherent uncertainties associated with this approach (see Section 3.5.1.2 and Box 3-7), it is recommended as an alternative method only in cases where data gaps necessitate such measures. The person wishing to utilize an EqP-based sediment PCL approach should clearly state the uncertainties in adopting such an approach, including a discussion of the data gaps that led to the conclusion that there are no other available sediment data for alternate means of deriving a benthic PCL.

7) The derivation of PCLs for aquatic life (water column receptors) does not parallel the derivation of PCLs for other media (e.g., benthic receptors in sediment) where a range is determined. Surface water PCLs are point values representing the TSWQS, values derived in

accordance with the TSWQS, or federal criteria.

8) The final media-specific ecological PCL for a COC should be the lowest concentration among the comparative PCLs determined for each relevant measurement receptor and the benthic community where appropriate. Accordingly, the measurement receptor or benthic community requiring the lowest comparative PCL is considered the most susceptible for that medium. Cost and remediation technology should never be factored into the determination of the final ecological PCL at this point. These are risk management considerations.

As stated previously, the guidelines listed above may vary between affected properties. Also, this list is by no means all-inclusive. The person should rely on site-specific circumstances and the availability of toxicological data to dictate the process for selection of comparative and final ecological PCLs.

Box 3-7: Advantages and Disadvantages of Using an Equilibrium Partitioning Method to Develop a Sediment PCL

The EqP estimation method explicitly assumes thermodynamic equilibrium, which is not necessarily true for sediments at all sites (SAB, 1990, 1992). The method, as typically applied, also does not account for the presence of dissolved organic carbon (DOC) within the pore water, variations in sediment particle sizes (e.g., DiToro, 1985; Weber et al., 1995) nor does it address issues such as irreversible adsorption, a characteristic of "aged" sediments (Karickhoff and Morris, 1985; Kelsey and Alexander, 1997; Hulscher et al., 1999; Kan et al., 1998). The EqP approach has also been criticized because it assumes that pore water is the only exposure pathway. Thus, the three main limitations of the EqP method are believed to be:

- the assumption of kinetic equilibrium;
- not considering the presence of competing partitioning compartments (DOC, clays, biota); and,
- not considering the additional exposure pathways to ecological receptors (e.g., sediment ingestion).

The first two limitations would lead to an overestimation of the pore-water chemical concentration that would be protective of benthic invertebrates, that is, the concentration estimated to protect receptors would be unnecessarily high. The third limitation could result in an underestimation of the PCL for a sediment-associated chemical.

If applied to a well-characterized sediment bed and COC, the EqP method can more realistically evaluate site-specific relevant receptors and measurement endpoints. The method is highly conservative for most COCs (i.e., those with moderate K_{ow} and K_{oc}) and will tend to over-estimate risks (a good false negative error rate) especially with high K_{oc} chemicals. In addition, the EqP approach will result in a more realistic false positive error rate than other approaches. The EqP method also can work well for multiple chemicals (i.e., address co-occurring chemical stressors). Given that additive, synergistic, and antagonistic effects due to co-occurring chemicals have been extensively studied in water exposures (e.g., Sprague, 1985, 1995; McCarty, 1991) the method can and has been adapted to co-occurring chemicals (e.g., Fuchsman et al., 1999). Additional adjustments of the method also appear effective in predicting toxic effects due to very low K_{ow} /K_{oc} type chemicals (Fuchsman et al., 2000). For chemicals with high K_{oc}s where sediment ingestion may be an issue, partitioning methods can still be used to predict tissue burdens (see Section 3.9.5.5) that can be used to calculate risk potentials based on residues (e.g., McCarty, 1991; Abernathy et al., 1988; U.S. ACE, 1992b, 1996a,b). For COCs with a log K_{oc} of less than 2, it is important to use the mathematically rigorous form of the equilibrium partitioning relationship (Fuchsman, 2003).

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6.3 Equilibrium Partitioning

As the use of EqP to develop sediment quality benchmarks and PCLs evolves in practice, (e.g., U.S. EPA, 1999a-d; DiToro et al., 2000; DiToro and McGrath, 2000; Fuchsman, 2003) TCEQ will continue to evaluate this concept and may increase its reliance on this approach. As it will be important for risk assessors to be aware of the latest technical advances in the use of EqP, interested persons are encouraged to monitor publications such as EPA's *Contaminated Sediments News*.

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APPENDIX A: Derivation of the Ecological Screening Benchmarks

Water Benchmarks

The benchmarks for surface water are intended to be protective of aquatic biota, and are not necessarily protective of mammalian and avian receptors that may be exposed to COCs through ingestion of contaminated prey or water. The following discussion details the derivation of the water benchmarks, provides guidance on the use of site-specific data, and provides a preferred hierarchy for selecting a water benchmark. (See Figure 3-4 also).

State and Federal Criteria

The State of Texas Surface Water Quality Standards (TNRCC, 2000b), as amended, will serve as the primary benchmarks for surface water, or in absence of a state standard, the federal National Ambient Water Quality Criteria (NAWQC) will be used (U.S. EPA, 2002). The benchmark values are provided in Table 3-2. The federal and state standards are generally protective of sensitive aquatic species, have undergone rigorous review and comment, and are generally accepted by the regulated community. Since a comparison of affected property concentrations to benchmarks is intended to be a screening step, the chronic criteria for the protection of aquatic life are used. The Texas Surface Water Quality Standards (TSWQS) define marine waters (or salt water) as coastal waters which have measurable elevation changes due to normal tides and further specifies that marine waters are generally considered to be coastal waters which typically have salinities of two parts per thousand or greater in a significant portion of the water column. This definition should be used to select the appropriate freshwater or marine water quality benchmark. The use of marine benchmarks for highly saline, yet inland, waters in West Texas is not appropriate. In a review of the European Centre for Ecotoxicology and Toxicology of Chemicals aquatic toxicity database, chemical sensitivities of marine and freshwater species varied between vertebrates and invertebrates depending on exposure duration, although the freshwater and salt water fish and invertebrates were within a factor of 10 in their sensitivity to 93% and 83% of all substances based on NOEC ratios (Hutchinson, et al., 1998).

For a number of metals, the fresh water criterion is a function of hardness. The benchmark values indicated in Table 3-2 are based on a hardness value of 50 mg/L. The person has several options for using an alternate hardness value to calculate the benchmark value. The person may use the segment specific 15th percentile hardness value (for the nearest downstream segment) as provided in the latest revision of the TCEQ's Implementation Procedures (TCEQ, 2003). Also, §350.74 (h)(5)(A) of TRRP provides that the person may use property-specific hardness data using site sample results in accordance with the latest revision of the TCEQ's Implementation

Procedures. Specific numerical aquatic life criteria for metals and metalloids apply to dissolved concentrations where noted. Dissolved concentrations can be estimated by filtration of samples prior to analysis, or by converting from total recoverable measurements in accordance with procedures approved by the commission in the latest revision of the TCEQ's Implementation Procedures (TCEQ, 2003). The TCEQ prefers dissolved metals data for surface waters, where appropriate, rather than the use of the mathematical conversion. If the conversion method is used, the person shall use the total suspended solids (TSS) concentration for the nearest classified downstream or downgradient segment, as provided in the Implementation Procedures, or the person may use property-specific TSS data from site sample results in accordance with the latest revision of the TCEQ's Implementation Procedures. A calculation example is provided in the box to the right. Since the Texas silver criterion is for the free ion form, persons should perform the dissolved to total calculation, in addition to the chloride-dependant estimation of the percent silver that is in the free ion form (see footnote s in Table 3-2). An example calculation is provided on the following page. Alternatively, the person may use the freshwater federal silver benchmark as provided in Table 3-2.

Example Dissolved to Total Conversion for Copper:

Segment 0806; West Fork of the Trinity River
Hardness = 140 mg/L (from Implementation Procedures, IPs)
TSS = 10 mg/L (from IPs)
Freshwater Chronic Standard for Dissolved Copper:

$$0.960e^{(0.8545(\ln(\text{hardness}))-1.386)} = 16.4 \text{ ug/L}$$

Determination of the Total Copper Number*:
Partition Coefficient, $K_d = 10^b \times TSS^m$

$$K_d = 10^{(6.02)} \times (10)^{-0.74}$$
$$K_d = 1.9055 \times 10^5$$

Fraction of Metal Dissolved = C/C_T

$$\frac{C}{C_T} = \frac{1}{1 + (K_d \times TSS \times 10^{-6})}$$

$$= \frac{1}{1 + (1.9055 \times 10^5)(10)(10^{-6})}$$

$$= 0.344$$

Total Chronic Standard = 16.4 ug/L ÷ 0.344 ≈ 48 ug/L

*See IPs for formulas and variables.

Collectively, the number of COCs for which state or federal water quality criteria are defined is minimal. In development of the benchmarks specified in this guidance, the TCEQ and the ecological guidance workgroup sought out other benchmarks for COCs that do not have specified criteria. Four primary sources were used for the derivation of these other water quality benchmarks. A preferred hierarchy for surface water benchmarks is depicted in Figure 3-4. Table 3-2 reflects one number (if available) that should be used for comparison of site surface water data to the screening benchmarks, since a preferred order of use accompanied the benchmark derivation. As a first tactic, the workgroup derived aquatic life numbers for a small number of COCs using the LC_{50} approach discussed in Section 3.5.1.1. These values are indicated by a “q” in Table 3-2. A full discussion of each value will be provided upon request from the TCEQ Technical Support Section. An example of the derivation process (for chloroform) is provided in the following section. The workgroup next selected the freshwater and marine water quality chronic values

derived by the TCEQ (2003a, Water Quality Division) for wastewater permits and requests from the Office of Waste, based primarily on the methodology defined in the TSWQS at 307.6(c)(7). Since the TCEQ water quality program routinely receives requests to develop "criteria" for COCs that do not have standards, the list of chronic values will be revised and expanded periodically. It is anticipated that the guidance will be updated via a posting on the TCEQ web site to reflect this new information.

The Tier II secondary chronic values (SCVs) developed by Suter and Tsao (1996) of the Oak Ridge National Laboratory (ORNL) were the third source for benchmark values selected by the workgroup. The SCVs rely on fewer data than the national criteria, and generally use the Great Lakes guidance method described in U.S. EPA (1993a), promulgated at 40 CFR Part 132, Appendix A. The Tier II values are concentrations that would be expected to be higher than the national water quality criteria in no more than 20% of the cases if ample test data was available to calculate a chronic criterion. The Tier II values developed by ORNL differ from those in the Great Lakes guidance in that the Great Lakes secondary acute values (SAVs) require an LC_{50} for a daphnid. ORNL used adjustment factors (See Appendix B of Suter and Tsao, 1996 and references given there) for calculating SAVs when the daphnid LC_{50} data is not available. The SAV is used to calculate the SCV. The Oak Ridge Tier II SCVs were derived for freshwater biota only.

Example Dissolved Free Ion to Total Conversion for Silver:

Segment 0604; Neches Below Lake Palestine
Hardness = 36 mg/L (from IPs*)
TSS = 10 mg/L (from IPs*)
Chlorides = 24 mg/L (from IPs*)
Freshwater Standard for the Free Ion form of
**Silver = 0.08 ug/L.

Determination of the % dissolved silver*:
Y = exp [exp (1/ (0.6559 + 0.0044(Cl)))]
= 41.18% dissolved silver.

Determination of the Total Silver Number*:
Partition Coefficient, $K_d = 10^b \times TSS^m$

$$K_d = 10^{(6.38)} \times (10)^{-1.03}$$
$$K_d = 2.239 \times 10^5$$

Fraction of Metal Dissolved = C/C_T

$$\frac{C}{C_T} = \frac{1}{1 + (K_d \times TSS \times 10^{-6})}$$

$$= \frac{1}{1 + (2.239 \times 10^5)(10)(10^{-6})}$$

$$= 0.31$$

Total Standard = 0.08 ug/L ÷((0.31)(.41)) = 0.63 ug/L
*See IPs for formulas and variables.
**Acute standard ÷ 10.

The last set of water quality benchmarks used are the U.S. EPA Region 4 chronic screening values (U.S. EPA Region 4, 2001). Both marine and freshwater values are provided. These numbers were derived by the Region 4 Water Management Division. For compounds without Federal criteria, the lowest chronic effect level reported in the applicable EPA ambient water quality criteria document was used with application of a safety factor of 10. When chronic values were not reported in the applicable EPA ambient water quality criteria document, the lowest acute effect level was used with application of a safety factor of 100. Finally, the State of Colorado's hardness-based freshwater standard for uranium was used (CDPHE, 2005), rather than the ORNL Tier II approach. In derivation of the criterion, Colorado used data from seven

toxicity tests involving 3 fish species over a range of hardness. This approach seemed more reasonable than ORNL's calculation using one species and 2 tests.

Example Aquatic Life Calculation Using the LC_{50} Approach for Chloroform (CAS: 67-66-3)

Fate and Transport in Water

When released into water, chloroform will be primarily lost by evaporation into the atmosphere due to its high Henry's Law constant of 3.68×10^{-3} atm-m^3/mole (TNRCC, 1999). Modeling studies suggest that the volatilization half-life is 36 hours in a river, 40 hours in a pond, and 9-10 days in a lake (U.S. EPA, 1984). Field monitoring data indicate the half-life of chloroform to be 1.2 days in the Rhine River and 31 days in a lake in the Rhine Basin (Zoeteman et al., 1980). Mackay et al. (1999) suggests a semi-quantitative classification of half-lives using nine different classes based on average environmental conditions. These half-life classes (i.e., referred to as reactivity classes) integrate reaction rates of the chemical for all relevant processes, including biodegradation, volatility, and photolysis. Chloroform is classified as Class 6 with a mean half-life of 1700 hours and a range of 1000 – 3000 hours. Howard et. al. (1991) indicates a half-life of 672 - 4320 hours in surface water, based on aqueous aerobic biodegradation. The reported fate and transport data for chloroform suggest that it is likely to persist in water environments for greater than 4 days. Based on these data, chloroform is considered to be persistent for the purposes of deriving the water quality value.

Sediment Benchmarks

The benchmarks for sediment are intended to be protective of benthic biota, and are not necessarily protective of mammalian and avian receptors that may be exposed to COCs through the food chain or via the incidental ingestion of sediment. Although there are a variety of existing sources for sediment benchmarks, most are derived using one of two basic approaches. The first general category is the correlative or integrative approach which relies largely on paired field and laboratory data to relate the incidence of adverse biological effects to the dry-weight sediment concentration of a COC. The toxicity values are derived through a number of approaches including toxicity tests of spiked sediment and field sediment, equilibrium partitioning (EqP), apparent effects threshold (AET), and benthic community surveys. Since these types of benchmarks rely in part on the total concentration of COCs in sediment as a basis for development, the resultant screening values may have no relationship with the actual toxicity of individual COCs in a mixture, or the ability of the COCs to bioaccumulate in aquatic or terrestrial organisms. The second approach (e.g. EqP) is theoretically based, and relies on the physical/chemical properties of sediment and COCs to predict the level of contamination that would not cause an adverse effect on aquatic life. In selection of the preferred sediment benchmarks specified in this guidance, the TCEQ and the ecological workgroup relied primarily on references that used the correlative approach, although EqP-based benchmarks were developed for VOCs.

Preferred Sediment Screening Benchmarks

The preferred benchmarks are provided in Table 3-3. The following sections discuss the sediment benchmark approaches that were evaluated, including those that were not chosen as preferred benchmarks. This discussion does not attempt to cover every possible sediment screening benchmark or method. These and other methodologies are discussed elsewhere (e.g. MacDonald, 1994; Neff, 1986; U.S. EPA, 1992; and Ingersoll, et al., 1997). Alternate sediment benchmarks, including those discussed in this guidance, may be used with appropriate justification. The use of alternate benchmarks is discussed in Section 3.5.1.

Freshwater Sediment Benchmarks

For freshwater benchmarks, the primary benchmarks selected were the Threshold Effect Concentrations (TECs) from MacDonald et al. (2000). Other sources include the Effects Range-Low (ER-L) values in Long and Morgan (1990), Lowest Effects Levels (LELs) from Persaud, et al. (1993), and the Interim Sediment Quality Guidelines (ISQG) from Environment Canada (1997). The values in Jones, et al. (1997) derived using the EqP approach were evaluated, but were not included in the listing of preferred benchmarks. However, EqP benchmarks were developed for VOCs by the ecological workgroup using TCEQ's LC_{50} database and the modified approach suggested by Fuchsman (2003). All of these approaches are discussed below.

MacDonald et al. Threshold Effect Concentrations (TEC)

MacDonald et al. (2000) has developed sediment guidelines for 29 COCs in freshwater sediments. Two values were developed - a threshold effect concentration (TEC), and a probable effect concentration (PEC). The TEC represents a sediment concentration below which adverse effects are not expected to occur, and the PEC represents a concentration above which adverse effects are expected to occur more often than not. Published sediment quality guidelines were compiled and divided into two categories depending on their original intent. Where three or more acceptable sediment guidelines were available for a COC, TECs and PECs were calculated by determining the geometric mean of the previously published sediment guidelines. The predictive ability of the TECs were evaluated using matching sediment toxicity and chemistry data from field studies. Concentrations in sediment were compared to the corresponding TEC for that COC and samples were predicted to be not toxic if the measured concentrations were lower than the corresponding TEC. The TEC was considered reliable if more than 75% of the sediment samples were correctly predicted to be not toxic. The authors concluded that most of the TECs (21 of 28) provide an accurate basis for predicting the absence of sediment toxicity. This included 4 trace metals, 8 individual PAHs, total PAHs, total PCBs, and 7 organochlorine pesticides.

Long and Morgan ER-Ls

This approach was first presented by Long and Morgan (1990) as part of the NOAA informal guidelines to help evaluate sediment chemistry data collected in the National Status and Trends Program (NSTP). The authors assembled a large sediment database that included effects and no effects field and lab data, for freshwater, estuarine, and marine organisms. COC concentrations (dry-weight normalized) observed or predicted by these methods to be associated with biological effects were ranked using percentiles. The lower 10th percentile concentration for those sediment COC concentrations associated with biological effects was defined as the ER-L value. Values below the ER-L were considered to represent the no effects range. The 50th percentile concentration for the ranked sediment COC concentrations associated with biological effects was defined as the effects range median (ER-M). COC concentrations between the ER-L and the ER-M values were considered to represent the possible effects range, and those above the ER-M were considered to represent the probable effects range. The ER-L values for antimony and silver were the only benchmarks used from this reference since other similar approaches (Smith, et al., 1996a) have incorporated more recent data sets.

Ontario Ministry of the Environment (OME) Lowest Effects Levels (LELs)

The OME derived sediment guidelines for evaluation of sediments throughout Ontario (Persaud, et al., 1993). They defined a LEL as a level of sediment contamination that can be tolerated by the majority of benthic organisms, and a severe effects level (SEL) as the level at which pronounced disturbance of the sediment-swelling community can be expected. These benchmarks were derived from matching sediment chemistry and benthic community data from

various geographic areas. OME used the Screening Level Concentration (SLC) approach as developed by Neff et al. (1986). This is a two-step process where a individual species SLC is first calculated for each COC by plotting the frequency distribution of the COC concentrations over all sites (at least 10) where that particular species is present. The 90th percentile is then selected as the SLC for that species. Then 90th percentiles for all the species present are plotted and the 5th (the LEL) and 95th (the SEL) percentiles are calculated. Hence the 5th percentile SLC (the LEL) is the COC concentration above which 95% of the species SLCs are found (the highest level of a COC that can be tolerated by 95% of the benthic species). The adequacy of the SLC is directly related to the size of the database and its variability. An advantage to this approach is that it is based on chronic population-level effects on indigenous biota and can be used for polar and ionic organics and metals as well as nonpolar organics. However it does not establish a direct cause and effect relationship between a single COC and benthic survival, and it requires a large amount of data including sediment analyses and benthic assessments. LELs for iron, manganese, several pesticides and individual Polychlorinated Biphenyl (PCB) aroclors were used as freshwater benchmarks in Table 3-3.

Interim Sediment Quality Guidelines (ISQG) from Environment Canada

Environment Canada (1997), describes the derivation of the Canadian freshwater and marine sediment quality guidelines for dichlorodiphenyltrichloroethane (DDT) and its degradation products, dichlorodiphenyldichloroethylene (DDE), and dichlorodiphenyldichloroethane (DDD). This reference was used in the guidance as the source for marine sediment benchmarks for Sum DDT, Sum DDE, or Sum DDE. The terms Sum DDT, Sum DDE, or Sum DDE are used to represent the sum of the concentrations of the *p,p′* and *o,p′* isomers. The reference provides interim sediment quality guidelines for sum DDD, sum DDE, and sum DDT for the protection of marine and estuarine life. Interim sediment quality guidelines for sum DDD and sum DDE for the protection freshwater aquatic life, and a provisional value for sum DDT for freshwater aquatic life are also provided but were not used. These values were developed in accordance with the procedures established by the CCME 1995 which relies on the NSTP approach (Long and Morgan, 1990) (with modifications) and the spiked-sediment toxicity test (SSTT) approach in combination. If insufficient information is available to derive interim guidelines, Canada uses other approaches or guidelines that may be adapted as a provisional ISQG. Modifications of the NSTP approach include the separate evaluation of information for freshwater and marine systems, an expanded data set, and use of derivation procedures that consider all compiled information (effect and no-effect data). All values are TELs with the exception of that for Sum DDE for freshwater sediments since the minimum data requirements (at least 20 entries in both the no-effect and effects data sets) were not met. Based on available data, Canada determined that freshwater and marine crustaceans are affected at similar concentrations of sum DDT, and they elected to use the marine ISQG as a provisional freshwater sediment value.

Equilibrium Partitioning (EqP) Approach

The TCEQ evaluated the use of this approach to expand the list of freshwater sediment benchmarks for organic COCs. The Oak Ridge National Laboratory (Jones et al., 1997) has used this approach to calculate benchmarks for 75 nonionic organic COCs. Although this database was not used, the ecological workgroup did use a modified EqP approach (Fuchsman, 2003) to develop freshwater and marine sediment benchmarks for 57 volatile COCs. EqP remains an alternative method for developing sediment benchmarks (and PCLs) provided there is adequate justification (see the EqP discussions in Sections 3.5.1.2, 3.13.2, and 6.3).

Marine Sediment Benchmarks

For marine benchmarks, the primary benchmarks selected were the ER-L values in Long et al. (1995). Other sources include the TELs from Smith, et al. (1996b), the ISQG from Environment Canada (1997), and the EqP-derived benchmarks for volatiles developed by the ecological workgroup. The Apparent Effects Threshold approach and the Florida TEL approach were evaluated, but were not used as preferred benchmarks. These approaches are discussed below (with the exception of Canada's ISQGs and the EqP benchmarks which have been previously discussed).

Long, et al., 1995 ER-Ls

Long, et al. (1995) established Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values from an updated version of the BEDS database developed by Long and Morgan (1990). Here, freshwater data was omitted, and new data was added. Like Long and Morgan (1990), studies included chemistry data and bioassays of field samples, toxicity tests using spikes of clean sediments, benthic community analyses, and equilibrium-partitioning modeling. No-effects data were separated from data where an effect was observed; then the effects data were sorted by increasing concentrations of each COC. For each COC, the ER-Ls and ER-Ms were defined as in Long and Morgan (1990).

Using amphipod survival bioassasys, O'Connor, et al. (1998) used the EPA Environmental Monitoring and Assessment Program - Estuaries (EMAP-E) and the NOAA Status and Trends Bioeffects Surveys to test the applicability of various sediment toxicity guidelines. Of the 481 samples without an ER-L exceedance, only 5% were determined to be toxic. The authors concluded that this was a good indication that toxic effects are unlikely at concentrations below an ER-L. Similarly, Long et al., 1998 found that the percentages of false negatives (toxic response) for ER-Ls and TELs were 11 and 9% respectively when synoptically collected chemistry and amphipod toxicity test data for 1,068 samples from studies compiled by EPA and NOAA during 1990 to 1993 were evaluated. The ER-L values for metals, PAHs, total DDTs, and total PCBs were the marine benchmarks used from this reference. The ER-L values have been widely used as screening tools in ecological risk assessments.

Canadian Sediment Quality Guideline (TELs) for Marine Waters

Smith, et al. (1996b) used CCME protocols (CCME, 1995) for the derivation of environmental quality guidelines. A modified version of the NSTP approach was used (Long and Morgan, 1990) and the NOAA BEDS database was used. The data for the effects data set and the no-effects data set were sorted for each COC and arranged in ascending order of COC concentrations. A TEL was calculated to be the geometric mean of the lower 15th percentile concentration of the effects data set, and the 50th percentile concentration of the no-effects data set. The TEL was intended to estimate the concentration for a given COC below which adverse biological affects only rarely occurred. The PEL was calculated to be the geometric mean of the 50th percentile concentration of the effects data set, and the 85th percentile of the no-effects data set. The PEL was intended to represent the concentration for a given COC above which adverse biological affects frequently occurred. TELs are draft interim sediment guidelines in the absence of adequate spiked-sediment toxicity test data. The marine TELs for chlordane, lindane, dieldrin and phthalates were used for this guidance.

Apparent Effects Thresholds (AET)

This methodology was first developed by Barrick et al. (1988) using empirical data from Puget Sound, Washington. The AET is the sediment concentration of a COC above which statistically significant ($p \leq 0.05$) biological effects are always expected. The AET values are empirically derived from paired (field and laboratory) sediment chemistry and biological effects measures such as sediment toxicity tests or benthic community surveys. The significance of adverse effects is assessed by statistical comparisons with suitable reference or control sediments. For a given data set, the AET value for a particular COC is the sediment concentration above which a particular adverse biological effect has always been found to be statistically significant, relative to a reference condition. Use of these values for a specific location or region elsewhere may be overprotective or under protective. The AET approach requires a large data base of COC data with at least one biological indicator. Unless site-specific data is used to derive an AET, the other benchmarks discussed in this guidance are presumed to be more appropriate in a Tier 2 ERA since the AET represents the sediment concentration above which statistically significant biological effects are always expected and therefore presents a substantial risk of under protection.

Florida Department of Environmental Protection TELs

The Florida Department of Environmental Protection used a similar weight-of-evidence approach to develop sediment quality guidelines for Florida coastal waters (MacDonald, 1994 and MacDonald et al., 1996). These guidelines were based on empirical analyses of data compiled from numerous field and laboratory studies performed for estuaries and bays throughout North America. As the Long et al. (1995) data set was used, only marine and estuarine data is included. Data was added, particularly for Florida and southeast Gulf of Mexico. Data for COCs in Florida

were retrieved and sorted in ascending COC concentration order. The data was sorted into an effects data set, and an no-effects data set, and a TEL and PEL were calculated for each constituent. This reference was not used since the TELs were essentially equivalent to those used by Smith et al. (1996b).

Other Marine Sediment Quality Guidelines for PAHs

In addition to PAH benchmarks proposed for individual and combined PAHs in this guidance, other methods have been proposed. Swartz, et al. (1995) proposed the ∑PAH model which predicts the probability of acute toxicity of PAH contaminated marine sediments using a combination of EqP, Quantitative Structure Activity Relationships (QSAR), toxic unit, additivity, and concentration-response models. Assuming that the toxic effects of PAHs are additive, the total number of toxic units of thirteen PAH compounds were used to predict the probability of toxicity to amphipods using a concentration-response model derived from spiked sediment toxicity tests. With inputs of f_{oc} and bulk concentrations of PAHs in sediment, the model predicts the probability that a sediment sample will be acutely toxic to amphipods (mortality >24%), not toxic (mortality <13%), or cause uncertain toxicity (mortality 13 to 24%).

The authors concluded that the model accurately predicts toxicity of PAH-contaminated sediments when PAHs are the principal COCs and the 13 PAHs used in the model development are the dominant PAHs. In another paper, (Swartz, 1999) discusses the "mixture paradox" for PAHs in that sediment quality guidelines derived from experimental determination of toxicological effects of individual PAHs (spiked-sediment tests) will greatly underestimate ecological effects in the field that are associated with the guideline but actually caused by the PAH mixture, whereas guidelines derived from the correlation of ecological effects with the concentration of an individual PAH in field-collected sediment will greatly overestimate the effects actually caused by the single compound. For this reason, the author believes that guidelines for individual PAHs are inappropriate. With PAH concentrations normalized for organic carbon, the author proposes guidelines for threshold (TEC) - 290 ug/g organic carbon (OC), median (MEC) 1,800 ug/g OC, and extreme (EEC) 10,000 ug/g OC effects concentrations as a mixture of total PAHs (TPAHs) in marine or estuarine sediments. The author concludes that the TEC is the most useful guideline because mixtures of PAHs are unlikely to cause adverse effects on benthic ecosystems below the TEC, and that the TPAH guidelines agree with others (EqP, ∑ PAH toxicity threshold, ER-L and SLC) within a factor of two.

Using Sediment Benchmarks to Derive PCLs for Benthic Communities

As detailed in Section 3.1.3.2 related to the selection of comparative and final PCLs, one approach to developing a PCL protective of the benthic invertebrate community employs the same databases used to derive the sediment screening benchmarks. The benchmarks listed in Table 3-3 were based on conservative primary effect levels such as the Effects Range-Low (ER-L) from Long and Morgan (1990), and the Threshold Effect Concentrations (TECs) from

MacDonald et al. (2000). For each of these values, there is a corresponding higher value that represents a second level of effects such as the Effects Range-Median (ER-M) from Long and Morgan (1990), and the Probable Effect Concentrations from MacDonald et al. (2000). These second effect levels appear in Table A-2. As indicated in Section 3.13.2, the person may view the primary effect levels as NOAELs and the second effect levels as LOAELs. In developing the benthic PCL, the same logic presented in the guidelines in Section 3.13.2 pertaining to NOAELs/LOAELs should be applied, with the understanding that the midpoint value may be proposed as the PCL but it is not a default (i.e., if sufficient evidence suggests that the midpoint is not protective, then this value will be questioned). Also, when using Tables 3-3 and A-2 to develop a sediment PCL for a volatile COC that was derived from the EqP approach, the person should remember that even though the surface water benchmarks and TCEQ's LC_{50} database were used as input, the resulting values are not effects-based for benthics and therefore it may be prudent to be conservative (i.e.,proposing a PCL that is less than the midpoint). This is particularly true when the acute surface water input number used to derive the second effects level was developed from equations in DiToro et al. (2000) as shown in the example box below. These values appear in Table A-2 with a "o" footnote. Alternatively, the person could use the acute-to-chronic ratio of 5.09 suggested in DiToro et al. (2000) and input a chronic surface water number into the sediment benchmark equation. In this case, the midpoint between the resulting values and the corresponding primary effect levels in Table 3-3 would be an acceptable PCL.

EXAMPLE CALCULATION OF ACUTE SURFACE WATER BENCHMARKS USING THE DITORO ET AL. METHOD

Step 1: DiToro et al., 2000, Equation 37 without the acute-to-chronic ratio (ACR):

$$\text{Log (WQB mmol/L)} = \text{Log (35.3)} + C_l - 0.945 \times \text{Log}(K_{ow})$$

Step 2: Units Conversion mmol/L to mg/L

WQB (mg/L) = WQB (mmol/L) x MW

Where:

WQB = acute water quality benchmark in surface water
C_l = chemical class correction (0 for aliphatic COCs, -0.244 for halogenated chemicals)
K_{ow} = octonal water partition coefficient (unitless)
MW = molecular weight (g/mol)

Example Calculation: Benzene (Log Kow = 1.99, MW = 78.1 g/mol)

Log (WQB) = Log (35.3) + 0 – 0.945 x 1.99
Log (WQB) = 1.55 – 1.88
Log (WQB) = -0.33
WQB = 0.47 mmol/L x 78.1 g/mol
WQB = 36.1 mg/L for Benzene

A chronic WQB can be obtained by dividing by the ACR of 5.09: 36.1 mg/L ÷ 5.09 = 7.09 mg/L

Example Calculation: Carbon Tetrachloride (Log Kow = 2.44 MW = 154 g/mol)

Log (WQB) = Log (35.3) –0.244 – 0.945 x 2.44
Log (WQB) = 1.55 – 0.244 – 2.31
Log (WQB) = -1.00
WQB = 0.100 mmol/L x 154 g/mol
WQB = 15.2 mg/L for Carbon Tetrachloride

A chronic WQB can be obtained by dividing by the ACR of 5.09:
15.2 mg/L ÷ 5.09 = 2.99 mg/L

Table A-2. Second Effects Levels for Sediment

CAS #	COC (mg/kg dry wt.)	Freshwater	Marine
Inorganics			
7440-36-0	Antimony	25 [a]	
7440-38-2	Arsenic	33	70
7440-43-9	Cadmium	4.98	9.6
7440-47-3	Chromium	111	370
7440-50-8	Copper	149	270
7439-89-6	Iron	40,000 [b]	
7439-92-1	Lead	128	218
7439-96-5	Manganese	1,100 [b]	
7439-97-6	Mercury	1.06	0.71
7440-02-0	Nickel	48.6	51.6
7440-22-4	Silver	2.2 [a]	3.7
7440-66-6	Zinc	459	410
Polycyclic Aromatic Hydrocarbons *Footnote (j) applies to all listed PAHs*			
83-32-9	Acenaphthene	0.089	0.500
208-96-8	Acenaphthylene	0.130	0.640
120-12-7	Anthracene	0.845	1.1
56-55-3	Benz(a)anthracene	1.05	1.6
50-32-8	Benzo(a)pyrene	1.45	1.6
218-01-9	Chrysene	1.29	2.8
53-70-3	Dibenz(a,h)anthracene	0.140 [k]	0.260
206-44-0	Fluoranthene	2.23	5.1
86-73-7	Fluorene	0.536	0.540
91-57-6	2- Methyl naphthalene		0.670
91-20-3	Naphthalene	0.561	2.1
85-01-8	Phenanthrene	1.17	1.5
129-00-0	Pyrene	1.52	2.6
	Low Molecular Weight PAHs		3.16 [e, i]
	High Molecular Weight PAHs		9.6 [f, i]
	Total PAHs	22.8 [g, i, j]	44.79 [g, i, j]
Chlorinated Pesticides/PCBs/Benzenes			
309-00-2	Aldrin	0.08 [b]	
27323-18-8	Aroclor 1254	0.34 [b]	
12674-11-2	Aroclor 1016	0.53 [b]	

Table A-2. Second Effects Levels for Sediment

CAS #	COC (mg/kg dry wt.)	Freshwater	Marine
11096-82-5	Aroclor 1260	0.24 [b]	
12672-29-6	Aroclor 1248	1.5 [b]	
319-84-6	alpha-BHC	0.1 [b]	
319-85-7	beta-BHC	0.21 [b]	
58-89-9	gamma-BHC (Lindane)	0.00499	0.00099 [d]
608-73-1	BHC	0.12 [b, i]	
57-74-9	Chlordane (Total)	0.0176	0.00479 [d]
60-57-1	Dieldrin	0.0618	0.00430 [d]
72-20-8	Endrin	0.207	
118-74-1	HCB (Hexachlorobenzene)	0.24 [b]	
1024-57-3	Heptachlor epoxide	0.016	
2385-85-5	Mirex	1.3 [b]	
72-55-9	Sum DDE	0.0313 [i]	0.374 [d, i]
72-54-8	Sum DDD	0.028 [i]	0.00781 [d, i]
50-29-3	Sum DDT	0.0629 [i]	0.00477 [d, i]
	Total DDT	0.572 [i]	0.046 [i]
1336-36-3	Total PCBs	0.676 [i]	0.180 [i]
Other Pesticides			
8001-35-2	Toxaphene	0.032 [m]	
Phthalates			
117-81-7	Bis(2-ethyl-hexyl)phthalate		2.647 [d]
	Di-n-butyl phthalate	0.043 [l]	
Volatiles *Footnote (n) applies to all listed volatiles unless otherwise noted*			
67-64-1	Acetone	360.18	1003.36
107-13-1	Acrylonitrile	1.36	1.04
71-43-2	Benzene [o]	45.01	45.01
104-51-8	N-butylbenzene	6.57	
103-65-1	Propyl benzene	4.35	
135-98-8	Sec-butylbenzene	5.28	
98-06-6	Tert-butylbenzene	7.26	
75-27-4	Bromodichloromethane	14.74	
78-93-3	2-butanone	154.26	
75-15-0	Carbon disulfide	0.78	

Table A-2. Second Effects Levels for Sediment

CAS #	COC (mg/kg dry wt.)	Freshwater	Marine
56-23-5	Carbon tetrachloride [o]	37.33	37.33
108-90-7	Chlorobenzene [o]	19.87	19.87
124-48-1	Chlorodibromomethane	0.94	
67-66-3	Chloroform (trichloromethane)	5.63	25.8
74-87-3	Chloromethane	106.8	52.43
98-82-8	Cumen	53.95	
99-87-6	p-Cymene	5.98	
95-50-1	1,2-dichlorobenzene	4.95	4.44
541-73-1	1,3-dichlorobenzene	0.35	1.95
106-46-7	1,4-dichlorobenzene	4.65	4.21
75-71-8	Dichlorodifluoromethane	22.09	
75-34-3	1,1-dichloroethane	13.89	
107-06-2	1,2-dichloroethane	28.69	25.80
75-35-4	1,1-dichloroethene	11.22	92.47
156-60-5	1,2-dichloroethene (trans)	71.84	
78-87-5	1,2-dichloropropane	13.17	
542-75-6	1,3-dichloropropene	1.37	0.26
100-41-4	Ethylbenzene	17.18	3.93
87-68-3	HCBD (Hexachlorobutadiene)	0.55 [m]	12.76 [n, o]
67-72-1	Hexachloroethane [o]	13.77	13.77
110-54-3	Hexane, n- [o]	12.77	
591-78-6	2-hexanone	28.20	
108-10-1	4-methyl-2-pentanone (MIBK)	116.59	272.06
74-83-9	Methyl bromide	0.46	2.49
22967-92-6	Methyl Mercury	N/A	
80-62-6	Methyl methacrylate	56.98	
75-09-2	Methylene chloride	46.52	22.91
98-95-3	Nitrobenzene [o]	161.06	161.06
71-41-0	1-Pentanol [o]	N/A	
67-63-0	2-Propanol [o]	443.99	
100-42-5	Styrene	61.42	22.31
79-34-5	1,1,2,2-tetrachloroethane	3.80	3.69
127-18-4	Tetrachloroethene	10.05	18.59
108-88-3	Toluene	17.29	5.66

Table A-2. Second Effects Levels for Sediment

CAS #	COC (mg/kg dry wt.)	Freshwater	Marine
75-25-2	Bromoform	1.31	10.67
120-82-1	1,2,4-trichlorobenzene	5.31	2.32
71-55-6	1,1,1-trichloroethane	24.80	15.83
79-00-5	1,1,2-trichloroethane	5.88	1.80
79-01-6	Trichloroethene	5.07	8.82
75-69-4	Trichlorofloromethane	10.12	
76-13-1	1,1,2-trichlorotrifluoroethane	16.70	
95-63-6	1,2,4-trimethylbenzene	4.58	12.95
108-67-8	1,3,5-trimethylbenzene	4.59	
108-05-4	Vinyl acetate [o]	366.29	
75-01-4	Vinyl chloride	11.78	
108-38-3	m-Xylene [o]	2.08	
1330-20-7	Xylenes	12.01	7.47

Freshwater - Unless otherwise noted, values are Threshold Effect Concentration (TEC) from: MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31.

Marine - Unless otherwise noted, values are Effects Range Median (ERM) from: Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environ. Manage. 19(1):81-97.

a Effects Range Median (ERM) from: Long, E.R. and L.G. Morgan. 1990. The Potential for Biological Effects of Sediment-sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52, March 1990.

b Severe Effects Level (SEL) from: Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Water Resources Branch. Ontario Ministry of the Environment and Energy. August.

c Probable Effect Levels (PEL) from: Environment Canada. 1997. Canadian Sediment Quality Guidelines for DDTs. Environment Canada, Guidelines and Standards Division. January, 1998 Draft.

d Probable Effect Level (PEL) from: Smith, S.L., D.D. MacDonald, K.A. Keenleyside, and C.L.

Table A-2. Second Effects Levels for Sediment

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e The sum of the concentrations of the following compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, and 2-methyl napthalene.

f The sum of the concentrations of the following compounds: fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene, and dibenzo [a,h]anthracene.

g The sum of the concentrations of each of low and high molecular weight PAHs listed above and any other PAH compounds that are COCs.

h Values in the original reference were based on percent total organic carbon. These values were converted to bulk sediment values by assuming 1% TOC (SEL x 0.01).

i When benchmarks represent the sum of individual compounds, isomers, or groups of congeners, and the chemical analysis indicates an undetected value, the proxy value specified at §350.51 (n) shall be used for calculating the sum of the respective compounds, isomers, or congeners. This assumes that the particular COC has not been eliminated in accordance with the criteria at §350.71 (k).

j The benchmarks for total PAHs are the most relevant in evaluating risk in an ERA as PAHs almost always occur as mixtures. Values for individual, low molecular weight, and high molecular weight PAHs are provided as guidelines to aid in the determination of disproportionate concentrations within the mixture that may be masked by the total. See discussion in Section 3.5.4.

k CCME (Canadian Council of Ministers of the Environment). 1999. Canadian environmental quality guidelines. Winnipeg, Manitoba.

l Cubbage, J., D. Batts, and S. Briedenbach. 1997. Creation and analysis of freshwater sediment quality values in Washington State. Environmental Investigations and Laboratory Services Program. Washington Department of Ecology. Olympia, Washington.

m NYSDEC (New York State Department of Environmental Conservation). 1999. Technical guidance for screening contaminated sediments. Division of Fish , Wildlife, and Marine Resources. Albany, New York. 36 pp.

n Benchmarks derived using formula in: Fuchsman, P.C. 2003. Modification of the Equilibrium Partitioning Approach for Volatile Organic Compounds in Sediment. Environ Toxicol Chem. 22:1532-1534. TCEQ's LC50 database used for water quality values, except where noted. TRRP-24 default values of 1% fraction organic carbon (f_{oc}) and 0.37 porosity were used. The person should adjust these values if sufficient site-specific data indicate they are not representative.

o Acute water quality values were used as input for these COCs and were derived from DiToro, D.M., J.A. McGrath, and D.J. Hansen. 2000. Technical basis for narcotic chemicals and polycyclic aromatic hydrocarbon criteria. I. Water and tissue. Environ. Toxicol. Chem. 19: pp

Table A-2. Second Effects Levels for Sediment

1951-1970.

Soil Benchmarks

The soil benchmarks provided in the guidance were chosen after a careful review of those available in the current scientific literature. The soil benchmarks provided here are considered to be the most relevant and useful of those currently available. The source documents of soil benchmarks that were reviewed include Efroymson, et al. (1997a, b, and c), and U.S. EPA Region 5 (1998). The U.S. EPA Region 5 Ecological Data Quality Limits (EDQLs) (U.S. EPA, 1998) were considered to be too conservative for use as ecological screening benchmarks. Their intended purpose is different from that of a screening criteria for a Tier 2 SLERA. The ORNL Preliminary Remediation Goal (PRG) values (Efroymson, et al., 1997a) were considered inappropriate because bioaccumulation is accounted for in their derivation, and bioaccumulation is considered as a separate exercise in the screening process in Tier 2. It should also be noted that most of the PRG values are equivalent to the benchmarks cited for either terrestrial plants or earthworms in the benchmark documents produced by ORNL for terrestrial plants and soil invertebrates, respectively.

The recommended soil benchmarks are the lower of the terrestrial plant and earthworm (or soil invertebrate) benchmark value from Efroymson, et al. (1997 b and c) and the Eco-SSLs developed by the U.S. EPA (U.S. EPA 2000, U.S. EPA 2003a, b and U.S. EPA 2005 a - h). The soil benchmark values, and their respective test organism source (i.e., plant, earthworm, or soil invertebrate) have been provided in Table 3-4. If the soil concentration is less than the associated soil benchmark, then that COC does not need further consideration in the ERA. However, if the COC concentration is greater than the associated soil benchmark, then that COC requires further evaluation (see Section 3.5). If the soil benchmark value in Table 3-4 for a particular COC is greater than the median Texas background concentration (or site-specific background concentration) cited for the same COC in this guidance, then the soil benchmark value may be ignored (See §§350.51(l) and 350.71(k) for a discussion of background concentrations).

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