Chapter 6

Numerical Sediment Quality Assessment Guidelines for Florida Coastal Waters

6.0 Introduction

State water quality criteria are one of the major management tools for protecting designated uses of coastal ecosystems, including maintenance of acceptable conditions for living resources. While state water quality criteria provide effective tools for managing water quality, they provide little guidance for managing sediment quality. Therefore, numerical sediment quality assessment guidelines (SQAGs) are required to help address concerns relative to contamination of coastal ecosystems with substances that tend to be associated with bed sediments. In particular, there is a need for SQAGs that apply to substances that are known or suspected to be present in Florida coastal sediments.

This Chapter presents the numerical SQAGs that have been developed for assessing sediment quality in Florida coastal waters. In total, threshold effect levels (TELs) and probable effects levels (PELs) have been derived for 34 substances or groups of substances. In addition, an indication of the subjective degree of confidence that should be placed on the SQAGs is provided. The detailed evaluation of these guidelines is presented in Chapter 7.

6.1 Identification of Priority Contaminants in Florida Coastal Waters

Generally, Florida's coast has not been subjected to extensive industrial developments. Therefore, the types of persistent, bioaccumulative, and highly toxic contaminants that are known to occur elsewhere in the United States are not likely to be distributed widely in its coastal areas. Nonetheless, various land uses and other coastal activities in the state have contributed significant quantities of environmental contaminants into coastal waters; therefore, sediments in the vicinity of major point and non-point sources may be severely contaminated. Concerns relative to the contamination of coastal ecosystems fall into four general categories: urban stormwater runoff; agricultural runoff; domestic wastewater; and, industrial wastewater (Hand *et al.* 1990). Consideration of each of these potential sources of environmental contaminants provides a basis for identifying chemical concerns in the Florida coastal zone.

It would be virtually impossible to develop SQAGs for every substance that could, potentially, be released into Florida coastal waters. For this reason, the evaluation of chemical concerns in Florida coastal systems is focused on identifying priority substances that are known to be released in significant quantities into receiving water systems and to form associations with sediments (Table 3). These substances are considered to be of highest priority with respect to developing numerical SQAGs applicable to Florida's coast.

Stormwater runoff and associated contaminants are of particular concern in Florida. While nutrients and sediments are the most prevalent pollutants in urban stormwater, metals, PAHs, and other toxic substances may also be transported into receiving water systems by runoff from urban areas. Due to the substantial population growth in recent years and the proximity of urban developments to the coast, urban stormwater represents a major source of contaminants into coastal ecosystems in Florida. Florida Department of Environmental Protection (FDEP 1994), Long and Morgan (1990), Delfino *et al.* (1991), and Long *et al.* (1991) provided lists of metals, PAHs, and other substances that have been detected at elevated levels in Florida coastal sediments (i.e., at levels that exceed the effects range low, ER-Ls, reported by Long and Morgan 1990). These substances are reflected in the preliminary evaluation of chemical concerns in Florida coastal ecosystems (Volume 2).

High yields of agricultural products in Florida require the use of substantial quantities of fertilizers and pesticides. However, poorly managed runoff from agricultural areas has the potential to severely affect receiving water systems. The principal contaminants associated with agricultural runoff include nutrients, suspended solids, herbicides, insecticides, and other pesticides. While agricultural runoff is known to have impacts on lakes, rivers, and canals in the immediate vicinity of agricultural operations, contaminants may also be transported into coastal waters. The high-use pesticides with significant potential to contaminate sediments in Florida's coastal areas are listed in Table 3. This list was assembled by considering present and historical pesticide use patterns (Pait *et al.* 1989), in conjunction with the physical/chemical properties of each substance (Worthing and Hance 1991). In addition, the pesticides which have been detected in coastal sediments (Long and Morgan 1990; Long *et al.* 1991; Delfino *et al.* 1991) or in aquatic biota (Trefry *et al.* 1983; Leslie 1990) in Florida were included in this list.

As might be expected in a state characterized by rapid urban development, inputs of domestic wastewater represent potentially significant sources of environmental contaminants. While wastewater treatment plant (WWTP) upgrades have resulted in improved water quality in many areas, progress towards effective management of domestic wastewater treatment plant effluents is hampered by rapid population growth and severe limitations on financial resources in some portions of the state (Hand *et al.* 1990). Environmental contaminants that are commonly associated with WWTP effluents include nutrients, metals, halogenated methanes, and various chlorinated organic substances (MacDonald 1989).

While Florida is generally not characterized by high densities of heavy manufacturing industries, substantial quantities of industrial wastewater are discharged into Florida waters

Table 3. Preliminary identification of chemicals of concern in Florida coastal waters.

Substance	Reference/Rationale
Metals	
Arsenic	Long et al. (1991); FDEP (1994).
Cadmium	Long et al. (1991); FDEP (1994).
Chromium	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Copper	Used in aquatic herbicides/found in fish; Long et al. (1991); Trefry et al. (1983); Leslie (1990); FDEP (1994).
Lead	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Mercury	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Nickel	Long et al. (1991); FDEP (1994).
Silver	Long and Morgan (1990); FDEP (1994).
Tributyltin	Used as an antifoulant on ships.
Zinc	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Polycyclic Aromatic Hydrocarbons (PAHs)	
Acenaphthene	Delfino et al. (1991); FDEP (1994).
Acenaphthylene	Delfino et al. (1991); FDEP (1994).
Anthracene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Benz(a)anthracene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Benzo(a)pyrene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Chrysene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Dibenzo(a,h)anthracene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Fluorene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Fluoranthene	FDEP (1994).
Napthalene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
2-methylnapthalene	Long and Morgan (1990).
Phenanthrene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Pyrene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Total PAHs	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Polychlorinated Biphenyls (PCBs)	
Total PCBs	Long and Morgan (1990); Long et al. (1991); Delfino et al. (1991); FDEP (1994).

Table 3. Preliminary identification of chemicals of concern in Florida coastal waters (continued).

Substance	Reference/Rationale
Pesticides	
Aldrin/Dieldrin	Long and Morgan (1990); Long et al.(1991); FDEP (1994).
Azinphos-methyl (guthi	Organophosphorous insecticide (Kow > 10,000?)
Chlordane	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Chlorothalonil	Chlorophenyl fungicide (Kow = 20,000)
Chlorpyrifos	Organophosphorous insecticide (Kow > 50,000)
DDT and metabolites	Long and Morgan (1990); Long et al. (1991); FDEP (1994); Delfino et al. (1991).
Disulfoton	Organophosphorous insecticide (Kow > 10,000)
Endosulfan	Delfino et al. (1991); FDEP (1994).
Endrin	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Heptachlor	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Heptachlor epoxide	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Lindane (gamma-BHC)	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Mirex	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Phorate	Organophosphorous insecticide (Kow > 10,000?).
Quintozene (PCNB)	Chlorophenyl fungicide (Kow = 10,000).
Toxaphene (alpha-BHC)	Organochlorine insecticide; FDEP (1994).
Trifluralin	Dinitroanaline herbicide (Kow > 200,000); FDEP (1994).
* Kow = Octanol-water partition coefficient which provides an indication of the hydrophobicity of a substance; Criteria for selection of pesticides: Kow > 5,000.	
Chlorinated Organic Compounds	
2,3,7,8-T4CDD	Pulp and paper industry.
2,3,7,8-T4CDF	Pulp and paper industry
Pentachlorophenol	Delfino et al. (1991); FDEP (1994).
Phthalates	
Bis(2-ethylhexyl)phthal	Delfino et al. (1991).
Dimethyl phthalate	Delfino et al. (1991).
Di-n-butylphthalate	Delfino et al. (1991).

(Farrow 1990). The major sources of these effluents are the pesticides, organic chemicals and plastics, petroleum refining, and pulp and paper industries (Farrow 1989; 1990). In addition to pesticides, metals, and PAHs (Long and Morgan 1990; Long *et al.* 1991; Delfino *et al.* 1991), industrial activities are likely to have resulted in the release of PCBs, polychlorinated dibenzo-*p*-dioxins (and related substances), and a wide variety of other organic contaminants into coastal waters (see MacDonald 1989 for a discussion on the nature and extent of contaminants that are typically associated with specific industrial wastewaters).

6.2 Numerical Sediment Quality Assessment Guidelines

Numerical sediment quality assessment guidelines have been developed for a total of 34 high priority substances in Florida. Using the procedures described in Chapter 5, a threshold effect level and a probable effect level were derived using the information contained in the expanded NSTP database. These numerical guidelines, which are expressed on a dry weight basis, are presented in Table 4. A brief discussion of the sources, fate, and effects of each substance (or group of substances) has also been prepared to provide additional information for applying the SQAGs. Lastly, the results of the evaluation of the reliability of the SQAGs are expressed as "high", "medium", and "low confidence" to provide guidance on the application of the SQAGs. However, the reader is urged to read Chapter 7 for the details of this evaluation, as well as an assessment of the comparability and predictability of the SQAGs.

6.2.1 Metals

Numerical SQAGs have been derived for nine metals that occur in Florida coastal sediments. As is the case for the other substances, the SQAGs are reported on a dry weight basis. While it is possible that further research could support the derivation of effects-based guidelines that are expressed in terms of the factors that influence bioavailability, such as acid volatile sulfide (AVS), the necessary data are not yet available. As discussed in Chapter 5, the preliminary guidelines should be used in conjunction with other assessment tools (such as the FDEP metals interpretive tool described in Volume 2) to evaluate sediment quality conditions in coastal waters.

Table 4. A summary of sediment quality assessment guidelines applicable to Florida coastal waters.

Substance	Total Number of Records	Number of Entries in the EDS	Number of Entries in the NEDS	Sediment Quality Assessment Guidelines	
				TEL	PEL
Metals (SQAGs in mg/kg)					
Arsenic	295	39	256	7.24	41.6
Cadmium	433	107	326	0.676	4.21
Chromium	354	53	301	52.3	160
Copper	440	105	335	18.7	108
Lead	402	95	307	30.2	112
Mercury	331	66	265	0.13	0.696
Nickel	355	23	332	15.9	42.8
Silver	190	35	155	0.733	1.77
Tributyltin	72	6	66	ID	ID
Zinc	411	96	315	124	271
Polychlorinated Biphenyls (PCBs; SQAGs in µg/kg)					
Total PCBs	199	65	134	21.6	189
Polycyclic Aromatic Hydrocarbons (PAHs; SQAGs in µg/kg)					
Acenaphthene	240	62	178	6.71	88.9
Acenaphthylene	209	36	173	5.87	128
Anthracene	259	70	189	46.9	245
Fluorene	263	73	190	21.2	144
2-methylnaphthalene	189	40	149	20.2	201
Naphthalene	256	57	199	34.6	391
Phenanthrene	268	74	194	86.7	544
Sum LMW-PAHs	274	69	205	312	1442

Table 4. A summary of sediment quality assessment guidelines applicable to Florida coastal waters (continued).

Substance	Total Number of Records	Number of Entries in the EDS	Number of Entries in the NEDS	Sediment Quality Assessment Guidelines TEL	PEL
Polycyclic Aromatic Hydrocarbons (PAHs; SQAGs in µg/kg)					
Benz(a)anthracene	249	63	186	74.8	693
Benzo(a)pyrene	259	68	191	88.8	763
Chrysene	258	68	190	108	846
Dibenzo(a,h)anthracene	246	54	192	6.22	135
Fluoranthene	279	85	194	113	1494
Pyrene	263	70	193	153	1398
Sum HMW-PAHs	274	64	210	655	6676
Total PAHs	250	58	192	1684	16770
Pesticides (SQAGs in µg/kg)					
Aldrin	180	15	165	ID	ID
Azinphos-methyl (Guthion)	0	0	0	ID	ID
Chlordane	203	25	178	2.26	4.79
Chlorthalonil	0	0	0	ID	ID
Chlorpyrifos	1	1	0	ID	ID
p,p'-DDD	173	22	151	1.22	7.81
p,p'-DDE	211	37	174	2.07	374
p,p'-DDT	175	26	149	1.19	4.77
Total DDT	89	37	52	3.89	51.7
Dieldrin	181	25	156	0.715	4.3
Disulfoton	0	0	0	ID	ID
Endosulfan	6	4	2	ID	ID
Endrin	146	14	132	ID	ID

Table 4. A summary of sediment quality assessment guidelines applicable to Florida coastal waters (continued).

Substance	Total Number of Records	Number of Entries in the EDS	Number of Entries in the NEDS	Sediment Quality Assessment Guidelines	
				TEL	PEL
Pesticides (SQAGs in µg/kg)					
Heptachlor	168	14	154	ID	ID
Heptachlor epoxide	137	9	128	ID	ID
Lindane (gamma-BHC)	181	21	160	0.32	0.99
Mirex	120	3	117	ID	ID
Phorate	0	0	0	ID	ID
Quintozene (PCNB)	0	0	0	ID	ID
Toxaphene (alpha-BHC)	133	4	129	ID	ID
Trifluralin	0	0	0	ID	ID
Chlorinated Organic Substances (SQAGs in µg/kg)					
2,3,7,8-Tetrachlorodibenzo-p-dioxin	18	2	16	ID	ID
2,3,7,8-Tetrachlorodibenzofuran	17	1	16	ID	ID
Pentachlorophenol	82	7	75	ID	ID
Phthalates (SQAGs in µg/kg)					
Bis(2-ethylhexyl)phthalate	131	31	100	182	2647
Dimethyl phthalate	86	10	76	ID	ID
Di-n-butyl phthalate	79	7	72	ID	ID

Total Number of Records = Number of data records in the expanded biological effects database for sediments.
All of the sediment quality assessment guidelines are expressed on a dry weight basis, as potential normalizers (e.g., Al, TOC, AVS) were rarely reported.
EDS = Effects data set: NEDS = No effects data set; TEL = Toxic effect level; PEL = Probable effect level.
ID = insufficient data to derive sediment quality assessment guidelines.
SQAG = Sediment quality assessment guidelines

Arsenic

Arsenic is released naturally into the environment due to the weathering of arsenic-rich rocks and volcanic activity. In addition to the natural sources of this substance, however, arsenic is released into the environment as a result of human activities. For example, arsenic is used in pigments, for medical purposes, in glass making, and in alloys with lead and copper. In addition, arsenic is also used in some pesticides (including herbicides), in plant defoliants, and in various preservatives. Any of these activities may result in contamination of aquatic resources with arsenic (CCREM 1987).

The majority of arsenic in surface water occurs in a soluble form which can be co-precipitated with hydrated iron and aluminum oxides, or adsorbed/chelated by suspended organic matter in sediments or humic substances in bottom sediments. Arsenic has a strong affinity for sulphur, and it readily adsorbs on and co-precipitates with other metal sulfides (Demayo *et al.* 1979).

The availability of arsenic in sediments to aquatic biota appears to be minimal under oxidizing conditions. Bioaccumulation of arsenic has been observed in numerous aquatic organisms, though there is no evidence that arsenic is biomagnified to a significant degree through the food web (Jaagumagi 1990a).

Exposure of aquatic organisms to arsenic-contaminated sediments may result in a variety of effects. While arsenic is known to be acutely toxic to aquatic biota, a variety of sublethal effects (including effects on the growth, reproduction, locomotion, behavior, and respiration) have also been observed in organisms exposed to arsenic (Eisler 1988). In mammals, exposure to arsenic has also been linked with a number of carcinogenic, mutagenic, and teratogenic effects.

Consideration of the available information on the toxicity of sediment-associated arsenic to aquatic biota results in the derivation of a ***TEL of 7.2 mg/kg and a PEL of 41.6 mg/kg***. An evaluation of the reliability of the SQAGs for arsenic suggests that a moderate degree of confidence can be placed on these guidelines.

Cadmium

Cadmium is a trace element used in a wide variety of applications, including electroplating, the manufacture of pigments, storage batteries, telephone wires, photographic supplies, glass, ceramics, some biocides, and as a stabilizer in plastics. In addition, cadmium may be present in phosphate rock used for fertilizers. The main anthropogenic sources of cadmium appear to be mining, metals smelting, industries involved in the manufacture of alloys, paints, batteries, and plastics, agricultural uses

of sludge, fertilizers and pesticides that contain cadmium, and the burning of fossil fuels (CCREM 1987).

In surface waters, cadmium generally occurs in the Cd(II) form as a constituent of inorganic (halides, sulfides, and oxides) and organic compounds. Transport of cadmium to the sediments occurs mainly through sorption to organic matter (and subsequent deposition) and through co-precipitation with iron, aluminum, and manganese oxides (Jaagumagi 1990a).

The availability of cadmium to aquatic biota is dependent on such factors as pH, redox potential, water hardness, and the presence of other complexing agents. Recently, Di Toro *et al.* (1991) presented evidence on the role of AVS in controlling the availability of cadmium. In general, cadmium is considered to have an extensive residence time and can accumulate to significant levels in biological tissues (Jaagumagi 1990a).

Exposure of aquatic organisms to cadmium can result in various adverse effects, including acute mortality, reduced growth, and inhibited reproduction (Eisler 1985a). In sediment, cadmium is toxic to marine amphipods at concentrations as low as 6.9 mg/kg (Swartz *et al.* 1985). Effects on the emergence, reburial, and avoidance behavior of marine amphipods have also been observed in spiked-sediment bioassays with cadmium (Long and Morgan 1990).

Consideration of the available information on the toxicity of sediment-associated cadmium to aquatic biota results in the derivation of a ***TEL of 0.68 mg/kg and a PEL of 4.2 mg/kg***. An evaluation of the reliability of the SQAGs for cadmium suggests that a high degree of confidence can be placed on these guidelines.

Chromium

Like cadmium, chromium is a trace metallic element widely used in industrial processes. Hexavelant chromium compounds are used in the metallurgical industry in the production of chrome alloy and chromium metal. In addition, these compounds are used in the chemical industry in chrome plating and in the production of paints, dyes, explosives, ceramics, and paper. Trivalent chromium salts are used in textile dyeing, in the ceramics and glass industry, and in photography (CCREM 1987). The main sources of chromium to the environment are emissions from the ferrochromium and metal plating industries, with coal and oil burning, refractory production, cement manufacturing, and the production of chromium steels representing relatively less important sources (Taylor *et al.* 1979).

In aquatic systems, chromium is present mainly in the Cr(III) and Cr(VI) forms. The Cr(VI) form is relatively soluble and does not tend to sorb onto particulate matter to any significant extent. Under anaerobic conditions, Cr(VI) may be reduced to Cr(III). In contrast to Cr(VI), Cr(III) readily sorbs onto organic particulates and co-precipitates with hydrous iron and manganese oxides. Under anoxic conditions in the sediments, Cr may also form insoluble sulfides (Jaagumagi 1990a).

Adverse biological effects associated with exposure to chromium include mortality and decreased growth, with plants being more sensitive than fish (CCREM 1987). While chromium is not accumulated to a significant degree by fish (BCF < 3; BCFs, bioconcentration factors are the ratio of tissue concentrations to concentrations in water), algal communities may concentrate this substance (BCF = 8500; CCREM 1987). Chromium(VI) is more readily accumulated than Cr(III) and is considered to be the more toxic form (Jaagumagi 1990a).

Consideration of the available information on the toxicity of sediment-associated chromium to aquatic biota results in the derivation of a ***TEL of 52.3 mg/kg and a PEL of 160 mg/kg***. An evaluation of the reliability of the SQAGs for chromium suggests that a moderate degree of confidence can be placed on these guidelines.

Copper

Copper is a common metallic element in crustal rocks and minerals. Natural sources of copper in aquatic environments include the weathering or the solution of copper-bearing minerals, copper sulfides, and native copper. Potential anthropogenic sources of copper include corrosion of brass and copper pipe by acidic waters, the use of copper compounds as aquatic algicides, sewage treatment plant effluents, runoff and groundwater contamination from agricultural uses of copper as fungicides and pesticides in the treatment of soils, and effluents and atmospheric fallout from industrial sources. Major industrial sources include mining, smelting and refining industries, copper wire mills, coal burning industries, and iron and steel producing industries (CCREM 1987).

Copper can exist in four oxidation states in aquatic systems, with Cu(I) and Cu(II) being the most common. In water, copper may form associations with organic matter and precipitates of hydroxides, phosphates, and sulfides. Formation of these complexes tends to facilitate transport to sediments. Under normal pH and redox conditions, copper tends to be present in sediments in the form of organic complexes, cupric carbonate complexes, and co-precipitates with iron and manganese oxides (Jaagumagi 1990a).

Copper is an essential micronutrient, and, therefore, it is readily accumulated by aquatic organisms (particularly in plants). However, no evidence exists to suggest that this substance is biomagnified in aquatic ecosystems (Jaagumagi 1990a). Copper is a broad spectrum biocide, which may be associated with acute and chronic toxicity, reduction in growth, interference with smoltification (the physiological changes that occur in preparation for the transition from freshwater to saltwater) in salmonids, and a wide variety of sublethal effects (Spear and Pierce 1979). There appears to be little difference in the sensitivity of aquatic organisms across taxonomic groups (CCREM 1987).

Consideration of the available information on the toxicity of sediment-associated copper to aquatic biota results in the derivation of a ***TEL of 18.7 mg/kg and a PEL of 108 mg/kg***. An evaluation of the reliability of the SQAGs for copper suggests that a moderate degree of confidence can be placed on these guidelines.

Lead

Lead occurs as a constituent in a variety of minerals. The single largest use of lead is in the production of lead-zinc batteries. The second largest use of lead is in the manufacture of chemical compounds, particularly alkyllead additives for gasolines. Lead and its compounds are also used in electroplating, metallurgy, construction materials, coatings and dyes, electronic equipment, plastics, veterinary medicines, fuels and radiation shielding. Other uses of lead are for ammunition, corrosive-liquid containers, paints, glassware, fabricating storage tank linings, transporting radioactive materials, solder, piping, cable sheathing, roofing and sound attenuators (CCREM 1987).

While lead may be present in three oxidation states in aquatic environments, Pb(II) is the most stable ionic species. In sediments, lead is primarily found in association with iron and manganese hydroxides, however, it may also form associations with clays and organic matter. Lead tends to remain tightly bound to sediments under oxidizing conditions, however, it may be released into the water column under reducing conditions (Jaagumagi 1990a).

Aquatic organisms exhibit a wide range of sensitivities to lead, with gastropods being particularly vulnerable. Aquatic plants appear to be relatively insensitive to the toxic effects of lead. Lead may be accumulated to relatively high levels by aquatic biota. Bioconcentration factors in algae may be as high as 20,000; however, BCFs for fish and invertebrates tend to be much lower (500 to 1700; CCREM 1987).

Consideration of the available information on the toxicity of sediment-associated lead to aquatic biota results in the derivation of a ***TEL of 30.2 mg/kg and a PEL of 112***

mg/kg. An evaluation of the reliability of the SQAGs for lead suggests that a moderate degree of confidence can be placed on these guidelines.

Mercury

Mercury is a trace element that occurs most commonly in the sulfide mineral cinnabar. Mercury is used in the production of chlorine, caustic soda and hydrogen, in the paint industry, in the pulp and paper industry, for electrical equipment, in medicinal compounds, and in thermometers. Mercury-based pesticides were once used in agriculture, however, the use of such pesticides has now been restricted (CCREM 1987). Anthropogenic sources to aquatic ecosystems can include waste incineration, coal combustion, paints, mining and smelting, and the chlor-alkali industry (Jaagumagi 1990a).

In aquatic systems, mercury is generally sorbed to particulate matter. In natural systems, mercury can exist in three oxidation states, including elemental Hg, Hg(I), and Hg(II). Both Hg(I) and Hg(II) can be methylated by microorganisms under anaerobic and aerobic conditions. In sediments, mercury tends to form associations with organic matter. Under anaerobic conditions, mercury may combine with sulphur to form insoluble sulfides (Jaagumagi 1990a).

Mercury is highly toxic to aquatic biota, with methylmercury being the most toxic form of the substance. Aquatic plants, invertebrates, and fish exhibit similar sensitivities to mercury, however, a great deal of variability exists within each of these groups. Mercury has the potential to accumulate to high levels in aquatic organisms, with BCFs as high as 85,000 observed in some fish species (CCREM 1987). Due to its high mammalian toxicity, bioaccumulation of mercury in fish and other aquatic species has significant implications with respect to human health.

Consideration of the available information on the toxicity of sediment-associated mercury to aquatic biota results in the derivation of a ***TEL of 0.13 mg/kg and a PEL of 0.70 mg/kg***. An evaluation of the reliability of the SQAGs for mercury suggests that a low degree of confidence can be placed on these guidelines.

Nickel

Nickel ranks as the 23rd element in order of abundance in the earth's crust and occurs naturally, mainly, in combination with sulphur, arsenic, and antimony. In ore deposits, it commonly occurs with iron and copper. Nickel is used, primarily, in the manufacturing of stainless steel, nickel plating, and other nickel alloys. Nickel is also used as a catalyst in industrial processes and in oil refining. More recently, it has been

used in nuclear power generating plants, gas turbine engines, cryogenic containers, and pollution abatement equipment. The most important anthropogenic sources of nickel include fossil fuel combustion, nickel ore mining, smelting and refining activities, and the electroplating industries (CCREM 1987).

In aquatic systems, nickel occurs primarily in the Ni(II) form. Nickel is deposited in sediments as a result of co-precipitation with iron and manganese oxides and sorption to organic matter. In sediments, nickel tends to form complexes with iron and manganese oxides, however, it may form insoluble complexes with sulfides under anaerobic conditions (Jaagumagi 1990a).

Exposure of aquatic organisms to nickel-contaminated sediments may result in a variety of adverse effects, including mortality, reduction in growth, and avoidance reactions. The toxicity of nickel increases in the presence of copper, therefore, synergism may be a factor that modifies the toxicity of this substance. While bioconcentration of nickel has been observed in a variety of organisms (particularly in annelids), biomagnification is not a significant concern in aquatic environments (CCREM 1987).

Consideration of the available information on the toxicity of sediment-associated nickel to aquatic biota results in the derivation of *a **TEL of 15.9 mg/kg and a PEL of 42.8 mg/kg***. An evaluation of the reliability of the SQAGs for nickel suggests that a low degree of confidence can be placed on these guidelines.

Silver

Silver is among the least common but most widely distributed elements in crustal rocks. Photographic materials represent the single largest use of silver. Other uses of this element include the manufacture of sterling and plated ware, jewellery, coins and medallions, electrical and electronic products, brazing alloys and solders, catalysts, mirrors, fungicides, and dental and medical supplies. Potential sources of silver to the aquatic environment include leachates from landfills, waste incineration, coal combustion, and effluents from the iron, steel and cement industries. In addition, wastewater treatment plants may also contribute significant loadings of silver to aquatic ecosystems (CCREM 1987).

In aqueous systems, silver may occur as elemental Ag, Ag(I), or Ag(II), however, ionic silver is primarily found in the univalent state. In water, silver may occur in colloidal form, sorbed to humic substances, and in various complexes with sulphur, arsenic, antimony, tellurium, and selenium. In sediments, silver tends to be found in association with manganese dioxide, sulphur, and various halides. Silver may also be adsorbed to organic material in sediments (CCREM 1987).

Silver is one of the most toxic metals to aquatic life. In general, plants are somewhat less sensitive than fish and aquatic invertebrates, with toxicity dependent primarily on metal speciation. Silver nitrate and silver iodide have been identified as highly toxic chemical species. Silver has a fairly low potential to accumulate in aquatic organisms, with BCFs ranging from less than 1 to 240 (CCREM 1987).

Consideration of the available information on the toxicity of sediment-associated silver to aquatic biota results in the derivation of a ***TEL of 0.73 mg/kg and a PEL of 1.77 mg/kg***. An evaluation of the reliability of the SQAGs for silver suggests that a moderate degree of confidence can be placed on these guidelines.

Tributyltin

Tributyltin is a member of a family of organotin compounds that are used in the production of plastics and as biocidal wood preservatives. Tributyltin oxide (TBTO) and tributyltin fluoride (TBTF) are the most important of the tributyltin compounds. Tributyltin oxide is used as a slimicide in cooling water towers, as a wood preservative, and as an antifouling additive in marine paint. The major use of TBTF is also as an antifouling agent in marine paint, and the use of both substances in marine paints represents potentially significant sources of tributyltin into aquatic ecosystems (CCREM 1987).

Tributyltin compounds are highly toxic to aquatic organisms (both plants and animals), as would be expected given their use as general biocides. Eisler (1985b) reported that tributyltins were capable of causing adverse biological effects at extremely low levels, and that these substances have been implicated as a major cause of reproductive failure in European flat oysters at several locations in recent years. Its high toxicity and significant potential for release into the aquatic environment make tributyltins a serious concern in marine sediments. While insufficient data are available to develop SQAGs (TEL and PEL) for tributyltin, extreme mortality (100%) has been observed in grass shrimp exposed (96 hour static test) to concentrations as low as 10 mg/kg (Clark *et al.* 1987). Since grass shrimp are a relatively insensitive test species, adverse effects on other organisms could be expected at concentrations well below this level.

Zinc

Zinc ranks as the 24th most abundant crustal element, occurring primarily as sulfide, carbonate, and silicate ores. Zinc is used in coatings to protect iron and steel, in alloys for die casting, in brass, in dry batteries, in roofing and exterior fittings for buildings, and in some printing processes. The principal sources of zinc to aquatic

systems include municipal wastewater effluents, zinc mining, smelting, and refining activities, wood combustion, waste incineration, iron and steel production, and other atmospheric emissions (CCREM 1987).

In aquatic systems, zinc occurs primarily as Zn(II), but can also form organozinc compounds. At neutral pH, zinc may be deposited in sediments by sorption to hydrous iron and manganese oxides, clay minerals, and organic matter. However, adsorption is very low at pHs below 6. Iron and manganese oxides/hydroxides appear to be the most important scavengers of zinc in coarse sediments that are low in organic matter. However, sorption to organic matter appears to be the most important environmental fate process in fine grained sediments. Under reducing conditions, organically-bound zinc generally forms insoluble sulfides (Jaagumagi 1990a).

Zinc is an essential micronutrient and uptake in most aquatic organisms appears to be independent of environmental concentrations. It has been found to bioaccumulate in some organisms, though there is no evidence of biomagnification (Jaagumagi 1990a). Aquatic organisms exhibit a wide range of sensitivities to zinc, however, there do not appear to be systematic differences in the toxicity of this substance between three major taxonomic groups (fish, invertebrates, and aquatic plants; CCREM 1987).

Consideration of the available information on the toxicity of sediment-associated zinc to aquatic biota results in the derivation of a ***TEL of 124 mg/kg and a PEL of 271 mg/kg***. An evaluation of the reliability of the SQAGs for zinc suggests that a moderate degree of confidence can be placed on these guidelines.

6.2.2 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) is the general term applied to a group of compounds comprised of several hundred organic substances with two or more benzene rings. They occur in the environment mainly as a result of incomplete combustion of organic matter (forest fires, internal combustion engines, wood stoves, coal, coke, etc.). They are also major constituents of petroleum and its derivatives, with oil spills and refinery effluents being major sources of PAH contamination to estuarine and marine environments (MacDonald *et al.* 1992). In addition, WWTP effluents and runoff from urban areas, particularly from roads, are known to contain significant quantities of PAHs. Furthermore, inputs of PAHs in aquatic ecosystems may occur as a result of oil spills, forest fires and agricultural burning, leaching from waste disposal sites, and coal gasification (Eisler 1987; Neff 1979; Campbell *et al.* 1979). PAHs are also produced by natural processes at very low rates (Blumer 1976).

In marine and estuarine environments, PAHs tend to form associations with suspended and deposited particulate matter (Eisler 1987). This sorption of PAHs to sediments is strongly correlated with the total organic carbon (TOC) content of sediments (Gillam 1991). Sediments contaminated with PAHs have been identified in a number of locations in the Florida coastal zone (Long and Morgan 1990). Substances detected most frequently in coastal sediments include acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene (Delfino *et al.* 1991). In general, elevated levels of sediment-associated PAHs in Florida are found in the vicinity of urban areas.

Exposure to PAHs may result in a wide range of effects on biological organisms. While some PAHs are known to be carcinogenic, others display little or no carcinogenic, mutagenic, or teratogenic activity (Neff 1979; EPA 1980, 1982a, b, c; NRCC 1983; Sims and Overcash 1983). Many carcinogenic PAHs also exhibit teratogenic and mutagenic effects. Several PAHs exhibit low levels of toxicity to terrestrial life forms, yet are highly toxic to aquatic organisms (Eisler 1987). The bioavailability (and hence, toxicity) of PAHs may depend on the concentration of TOC in the sediment (Bolton *et al.* 1985; Lyman *et al.* 1987).

Acenaphthene

Consideration of the available information on the toxicity of sediment-associated acenaphthene to aquatic biota results in the derivation of a ***TEL of 6.7 μg/kg and a PEL of 88.9 μg/kg***. An evaluation of the reliability of the SQAGs for acenaphthene suggests that a moderate degree of confidence can be placed on these guidelines.

Acenaphthylene

Consideration of the available information on the toxicity of sediment-associated acenaphthylene to aquatic biota results in the derivation of a ***TEL of 5.9 μg/kg and a PEL of 128 μg/kg***. An evaluation of the reliability of the SQAGs for acenaphthylene suggests that a moderate degree of confidence can be placed on these guidelines.

Anthracene

Consideration of the available information on the toxicity of sediment-associated anthracene to aquatic biota results in the derivation of a ***TEL of 46.9 μg/kg and a PEL of 245 μg/kg***. An evaluation of the reliability of the SQAGs for anthracene suggests that a high degree of confidence can be placed on these guidelines.

Fluorene

Consideration of the available information on the toxicity of sediment-associated fluorene to aquatic biota results in the derivation of a ***TEL of 21.2 μg/kg and a PEL of 144 μg/kg***. An evaluation of the reliability of the SQAGs for fluorene suggests that a moderate degree of confidence can be placed on these guidelines.

2-methylnaphthalene

Consideration of the available information on the toxicity of sediment-associated 2-methylnaphthalene to aquatic biota results in the derivation of a ***TEL of 20.2 μg/kg and a PEL of 201 μg/kg***. An evaluation of the reliability of the SQAGs for 2-methylnaphthalene suggests that a high degree of confidence can be placed on these guidelines.

Naphthalene

Consideration of the available information on the toxicity of sediment-associated naphthalene to aquatic biota results in the derivation of a ***TEL of 34.6 μg/kg and a PEL of 391 μg/kg***. An evaluation of the reliability of the SQAGs for naphthalene suggests that a high degree of confidence can be placed on these guidelines.

Phenanthrene

Consideration of the available information on the toxicity of sediment-associated phenanthrene to aquatic biota results in the derivation of a ***TEL of 86.7 μg/kg and a PEL of 544 μg/kg***. An evaluation of the reliability of the SQAGs for phenanthrene suggests that a high degree of confidence can be placed on these guidelines.

Total Low Molecular Weight PAHs

The group of low molecular weight (LMW) PAHs considered in the present study includes acenaphthene, acenaphthylene, anthracene, fluorene, 2-methylnaphthalene, naphthalene, and phenanthrene. Due to their similar mode of toxic action, these substances are frequently considered together in toxicity assessments (e.g., Gillam 1991). Consideration of the available information on the toxicity of sediment-associated total LMW PAHs to aquatic biota results in the derivation of a ***TEL of 312 μg/kg and a PEL of 1440 μg/kg***. An evaluation of the reliability of the SQAGs for total LMW PAHs suggests that a high degree of confidence can be placed on these guidelines.

Benz(a)anthracene

Consideration of the available information on the toxicity of sediment-associated benz(a)anthracene to aquatic biota results in the derivation of a ***TEL of 74.8 μg/kg and a PEL of 693 μg/kg***. An evaluation of the reliability of the SQAGs for benz(a)anthracene suggests that a moderate degree of confidence can be placed on these guidelines.

Benzo(a)pyrene

Consideration of the available information on the toxicity of sediment-associated benzo(a)pyrene to aquatic biota results in the derivation of a ***TEL of 88.8 μg/kg and a PEL of 763 μg/kg***. An evaluation of the reliability of the SQAGs for benzo(a)pyrene suggests that a high degree of confidence can be placed on these guidelines.

Chrysene

Consideration of the available information on the toxicity of sediment-associated chrysene to aquatic biota results in the derivation of a ***TEL of 108 μg/kg and a PEL of 846 μg/kg***. An evaluation of the reliability of the SQAGs for chrysene suggests that a high degree of confidence can be placed on these guidelines.

Dibenzo(a,h)anthracene

Consideration of the available information on the toxicity of sediment-associated dibenzo(a,h)anthracene to aquatic biota results in the derivation of a ***TEL of 6.2 μg/kg and a PEL of 135 μg/kg***. An evaluation of the reliability of the SQAGs for dibenzo(a,h)anthracene suggests that a moderate degree of confidence can be placed on these guidelines.

Fluoranthene

Consideration of the available information on the toxicity of sediment-associated fluoranthene to aquatic biota results in the derivation of a ***TEL of 113 μg/kg and a PEL of 1490 μg/kg***. An evaluation of the reliability of the SQAGs for fluoranthene suggests that a high degree of confidence can be placed on these guidelines.

Pyrene

Consideration of the available information on the toxicity of sediment-associated pyrene to aquatic biota results in the derivation of a ***TEL of 153 μg/kg and a PEL of 1400 μg/kg***. An evaluation of the reliability of the SQAGs for pyrene suggests that a high degree of confidence can be placed on these guidelines.

Total High Molecular Weight PAHs

The group of high molecular weight (HMW) PAHs considered in the present study consists of benz(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, and pyrene. Due to similarities in their mode of action and toxic effect levels, these substances are frequently considered together in sediment quality assessments (Gillam 1991). Consideration of the available information on the toxicity of sediment-associated total HMW PAHs to aquatic biota results in the derivation of a ***TEL of 655 μg/kg and a PEL of 6680 μg/kg***. An evaluation of the reliability of the SQAGs for total HMW PAHs suggests that a moderate degree of confidence can be placed on these guidelines.

Total PAHs

Total PAHs refers to the sum of the concentrations of each of the 13 low and high molecular weight PAHs listed in the previous sections. While the mode of action of LMW and HMW PAHs is thought to differ (MacDonald *et al.* 1992), these substances are sometimes grouped in assessments of sediment quality (Gillam 1991). Consideration of the available information on the toxicity of sediment-associated total PAHs to aquatic biota results in the derivation of a ***TEL of 1680 μg/kg and a PEL of 16800 μg/kg***. An evaluation of the reliability of the SQAGs for total PAHs suggests that a high degree of confidence can be placed on these guidelines.

6.2.3 Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) is the generic term for a group of 209 congeners that contain a varying number of substituted chlorine atoms in a biphenyl ring. Commercially, PCBs are used in complex mixtures, based primarily on the percentage of chlorine in the mixture. Mixtures containing 21 - 54% chlorine by weight have been used extensively in closed electric systems as dielectric fluids. Other PCBs have been used as plasticizers, heat

transfer fluids, hydraulic fluids, fluids in vacuum pumps and compressors, lubricants, wax extenders, special adhesives, and surface coatings for carbonless copy paper (Moore and Walker 1991). However, all of these uses were curtailed in the United States in 1971.

Contamination of aquatic ecosystems by PCBs has arisen exclusively from human activities. While PCBs may enter the environment from a variety of sources, the major inputs to aquatic systems include leachates from landfills, municipal wastewater effluents, industrial effluents, atmospheric deposition (due to incomplete incineration of PCB contaminated wastes), and disposal of industrial and municipal wastewater treatment sludges (Moore and Walker 1991).

PCBs are highly persistent, stable compounds, which have high octanol/water partition coefficients. As such, sorption to sediments is a predominant environmental fate process in aquatic systems (Jaagumagi 1990a). PCBs tend to be associated with fine grained particles (< 0.15 μm) and organic matter in sediments. As is the case with many non-polar organic contaminants, the bioavailability of PCBs may depend on the TOC content of the sediments (Bolton *et al.* 1985; Lyman *et al.* 1987).

Exposure to PCBs may result in a wide variety of effects on aquatic organisms, including acute and chronic lethality, reproductive toxicity, developmental abnormalities, and growth retardation (Moore and Walker 1991). While PCBs are not highly toxic to aquatic organisms, these substances have considerable potential to accumulate in the tissues of aquatic species and, therefore, may represent significant hazards to consumers of aquatic species. Bioaccumulation factors for PCBs have ranged as high as 4.4×10^7 in laboratory studies and biomagnification in higher trophic levels has been demonstrated (Moore and Walker 1991).

Consideration of the available information on the toxicity of sediment-associated total PCBs to aquatic biota results in the derivation of a ***TEL of 21.6 μg/kg and a PEL of 189 μg/kg***. An evaluation of the reliability of the SQAGs for total PCBs suggests that a low degree of confidence can be placed on these guidelines.

6.2.4 Pesticides

A wide variety of pesticides are used in agricultural and other applications throughout Florida. A list of the substances of greatest concern with respect to contamination of coastal sediments is provided in Table 3. These substances were identified based on historic and current use patterns (i.e., > 100,000 pounds applied in Florida annually), physical/chemical properties (i.e., log K_{ow}), and existing sediment quality monitoring data (Long and Morgan 1990; Long *et al.* 1991; Delfino *et al.* 1991).

Sufficient toxicological data exist to develop SQAGs for only a subset of the priority pesticides used in Florida. Additional information will be required to support the derivation of guidelines for the other priority pesticides in Florida coastal waters.

Aldrin/Dieldrin

Aldrin is an organochlorine pesticide that has been used as a pest control agent in a variety of domestic and agricultural applications (Jaagumagi 1990b). Originally, aldrin was used to control a broad spectrum of soil, fruit, and vegetable pests, as well as for specific control of grasshoppers, locusts, and termites (CCREM 1987). However, the current uses of aldrin are restricted to those situations where there is no effluent discharge (i.e., ground injection for termite control; CCREM 1987). In aquatic systems, aldrin is rapidly biotransformed (through epoxidation) to dieldrin, which is highly stable in aquatic environments.

Like aldrin, dieldrin is an organochlorine pesticide. Dieldrin has been one of the most widely used domestic pesticides in the United States (CCREM 1987), primarily to control soil, fruit, and vegetable pests. As is the case with aldrin, dieldrin use is currently restricted to situations where there is no effluent discharge (CCREM 1987). Sorption to sediments is an important environmental fate process for dieldrin. In sediments, this substance may persist for extended periods. Dieldrin has been detected in coastal sediments at a number of locations throughout Florida (Long and Morgan 1990).

Consideration of the available information on the toxicity of sediment-associated dieldrin to aquatic biota results in the derivation of a ***TEL of 0.72 μg/kg and a PEL of 4.3 μg/kg***. An evaluation of the reliability of the SQAGs for dieldrin suggests that a moderate degree of confidence can be placed on these guidelines.

Azinphos-methyl

Insufficient data were available to develop SQAGs for azinphos-methyl, which is also known as guthion.

Total Chlordane

Chlordane is a broad spectrum chlorinated hydrocarbon pesticide that occurs as a mixture of isomers, the most common of which are alpha-chlordane and gamma-chlordane (Jaagumagi 1990b). Chlordane has been used in a wide variety of agricultural and domestic applications in Florida. Specifically, it has been used as a wood preservative, as an insecticide in home and garden applications, and to control pests on livestock (Worthing and Hance 1991). While the use of this compound has been discontinued in recent years, its persistence and tendency to accumulate in

sediments makes chlordane an ongoing concern in Florida sediments. This substance has been detected in coastal sediments in various locations in the state (Long and Morgan 1990).

Consideration of the available information on the toxicity of sediment-associated total chlordane to aquatic biota results in the derivation of a ***TEL of 2.3 μg/kg and a PEL of 4.8 μg/kg***. An evaluation of the reliability of the SQAGs for chlordane suggests that a low degree of confidence can be placed on these guidelines.

Chlorthalonil

Insufficient data were available to develop SQAGs for chlorthalonil.

Chlorpyrifos

Insufficient data were available to develop SQAGs for chlorpyrifos.

DDT and Metabolites

DDT or 1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane is a broad spectrum organochlorine insecticide that has been used worldwide since the early 1940s (Jaagumagi 1990b). DDT has been used extensively in agricultural applications, primarily as a non-systemic ingested and contact insecticide to control a wide variety of pest species (Worthing and Hance 1991). While this substance is no longer registered for use in North America, it is highly toxic and persistent in the environment. Therefore, residues of DDT and its metabolites (DDE and DDD) may represent significant sediment quality concerns in Florida. DDT, DDE, and DDD have all been detected recently in Florida coastal sediments (Delfino *et al.* 1991; Long and Morgan 1990).

p,p'-DDD

Consideration of the available information on the toxicity of sediment-associated p,p'-DDD to aquatic biota results in the derivation of a ***TEL of 1.2 μg/kg and a PEL of 7.8 μg/kg***. An evaluation of the reliability of the SQAGs for p,p'-DDD suggests that a moderate degree of confidence can be placed on these guidelines.

p,p'-DDE

Consideration of the available information on the toxicity of sediment-associated p,p'-DDE to aquatic biota results in the derivation of a ***TEL of 2.1 μg/kg and a PEL of 374 μg/kg***. An evaluation of the reliability of the SQAGs for p,p'-DDE suggests that a moderate degree of confidence can be placed on these guidelines.

p,p'-DDT

Consideration of the available information on the toxicity of sediment-associated p,p'-DDT to aquatic biota results in the derivation of a ***TEL of 1.2 μg/kg and a PEL of 4.8 μg/kg***. An evaluation of the reliability of the SQAGs for p,p'-DDT suggests that a moderate degree of confidence can be placed on these guidelines.

Total DDT

Consideration of the available information on the toxicity of sediment-associated total DDT (the sum of the concentrations of *p,p'*-DDT, *o,p'*-DDT, *p,p'*-DDE, *o,p'*-DDE, *p,p'*-DDD, *o,p'*-DDD) to aquatic biota results in the derivation of a ***TEL of 3.89 μg/kg and a PEL of 51.7 μg/kg***. An evaluation of the reliability of the SQAGs for total DDT suggests that a low degree of confidence can be placed on these guidelines.

Disulfoton

Insufficient data were available to develop SQAGs for disulfoton.

Endosulfan

Insufficient data were available to develop SQAGs for endosulfan. McLeese *et al.* (1982) reported a 12 day LC_{50} of 340 μg/kg for the sandworm, *Nereis virens.* Chandler and Scott (1991) reported effects on colonization of polychaetes in South Carolina at 50 μg/kg and mortality to copepods at 200 μg/kg.

Endrin

Insufficient data were available to develop SQAGs for endrin. Chronic marine sediment quality criteria, calculated using the EqPA, ranged from 0.53 to 3.21 μg/kg

(EPA 1988; JRB Associates 1984). More recently, Hansen *et al.* (1993a) reported a chronic SQC of 7.6 µg/kg at 1% OC.

Heptachlor

Insufficient data were available to develop SQAGs for heptachlor. The chronic marine sediment quality criterion, calculated using the EqPA, was 5 µg/kg (Bolton *et al.* 1985).

Heptachlor Epoxide

Insufficient data were available to develop SQAGs for heptachlor epoxide.

Lindane

Consideration of the available information on the toxicity of sediment-associated lindane (gamma-BHC) to aquatic biota results in the derivation of a ***TEL of 0.32 µg/kg and a PEL of 0.99 µg/kg***. An evaluation of the reliability of the SQAGs for lindane suggests that a low degree of confidence can be placed on these guidelines.

Mirex

Insufficient data were available to develop SQAGs for mirex.

Phorate

Insufficient data were available to develop SQAGs for phorate.

Toxaphene

Insufficient data were available to develop SQAGs for toxaphene. Bolton *et al.* (1985) reported a chronic marine sediment quality criterion of 5 µg/kg for this substance.

Trifluralin

Insufficient data were available to develop SQAGs for trifluralin.

6.2.5 Chlorinated Organic Substances

Dioxins and Furans

Polychlorinated dibenzo-*p*-dioxins (PCDDs) are composed of a triple-ring structure consisting of two benzene rings connected to each other by two oxygen atoms. Depending on the number and position of chlorine substitution on the benzene rings, 75 chlorinated dioxin congeners are possible. The polychlorinated dibenzofuran (PCDF) molecule is also a triple-ring structure with the two benzene rings connected to themselves by a single oxygen atom. One hundred and thirty-five (135) chlorinated dibenzofuran congeners are possible.

Sources and releases to the environment have been well documented in the literature (OMOE 1985; Hutzinger *et al.* 1985; EPA 1985; NRCC 1981; NRCC 1984). Dioxins and furans are not produced intentionally but are unavoidable by-products of chemical manufacturing or the result of incomplete combustion of materials containing chlorine atoms and organic compounds (OMOE 1985). Dioxins and furans may also be formed during the disinfection of complex effluents (e.g. pulp and paper effluents) containing many organic constituents.

Dioxins and furans have the potential to enter the aquatic environment due to direct effluent discharges, runoff from areas in which dioxin/furan contaminated products are used and stored, and deposition of materials that are transported atmospherically. The most significant sources of dioxins include the wood preservative pentachlorophenol, municipal incinerators, and pulp and paper mills that utilize chlorine in the bleaching process. Polychlorinated biphenyls (PCBs) are the most significant source of furans (Boddington *et al.* 1990).

Dioxins and furans may be distributed throughout the environment via air, water, soil, and sediments. Dioxins and furans tend to be very insoluble in water, adsorb strongly onto soils, sediments, and airborne particulates, and bioaccumulate in biological tissues (Hutzinger *et al.* 1985). These substances have been associated with a wide variety of toxic effects in animals, including acute toxicity, enzyme activation, tissue damage, developmental abnormalities, and cancer.

Insufficient toxicological data are available to derive SQAGs for any of the 75 dioxin or furan congeners that could be present in Florida coastal sediments.

Pentachlorophenol

Insufficient data were available to develop SQAGs for pentachlorophenol. In Puget Sound, AETs of 360 and 690 μg/kg have been reported for amphipods and benthic species, respectively (PTI 1988).

6.2.6 Phthalate Esters

Phthalate esters represent a large group of chemicals that are used widely as plasticizers in polyvinyl chloride (PVC) resins, adhesives, and cellulose film coatings. They are also found in cosmetics, rubbing alcohol, insect repellents, insecticides, and solid rocket propellants (CCREM 1987). Due to their wide use, phthalate esters have a significant potential to be released into coastal ecosystems. For this reason, numerical SQAGs for these substances are required to assess the hazards posed to aquatic organisms.

Bis(2-ethylhexyl)phthalate

Consideration of the available information on the toxicity of sediment-associated bis(2-ethylhexyl)phthalate to aquatic biota results in the derivation of a ***TEL of 182 μg/kg and a PEL of 2650 μg/kg***. An evaluation of the reliability of the SQAGs for bis(2-ethylhexyl)phthalate suggests that a high degree of confidence can be placed on these guidelines.

Dimethyl phthalate

Insufficient data were available to develop SQAGs for dimethyl phthalate. Puget Sound AETs ranged from 71 μg/kg (Microtox) to > 160 μg/kg (amphipods and bivalves) for this substance (PTI 1988; Bellar *et al.* 1986). Bolton *et al.* (1985) reported a chronic marine sediment quality criterion of 490 μg/kg, using the EqPA.

Di-n-butyl phthalate

Insufficient data were available to develop SQAGs for di-n-butyl phthalate. Puget Sound AETs ranged from 1400 μg/kg (Microtox and oysters) to > 5100 μg/kg (benthic species) for this substance (PTI 1988; Bellar *et al.* 1986).