

**STATUS OF TAMPA BAY SEDIMENTS:  
POLYCYCLIC AROMATIC  
HYDROCARBONS,  
ORGANOCHLORINE PESTICIDES,  
AND  
POLYCHLORINATED BIPHENYLS  
(1993 & 1995-1999)**

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# **Environmental Protection Commission of Hillsborough County**

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# SECTION I

## INTRODUCTION

Tampa Bay sediments have been the object of intensive investigations by the University of South Florida (Doyle *et al.* 1985; Doyle *et al.* 1989; Brooks & Doyle 1991 & 1992), the National Oceanographic & Atmospheric Administration (Long *et al.* 1991; Long *et al.* 1994; Daskalakis & O'Connor 1994; Long *et al.* 1995a; Carr *et al.* 1996), and the Florida Department of Environmental Protection (Seal *et al.* 1994). Coastal Environmental, Inc. (1996) summarized the results of several of these investigations. Recently Grabe (1997) summarized trace metal contamination of Tampa Bay sediments based upon a random probability-based sampling regimen. This companion report summarizes contamination of Tampa Bay sediments by three classes of organic compounds: organochlorine pesticides [OCLs], polycyclic aromatic hydrocarbons [PAHs], and polychlorinated biphenyls [PCBs].

Synthetic pesticides have been widely used in the U.S. since World War II, starting with the synthesis and application of the OCL DDT (Nimmo 1979). OCLs, which tend to be long-lived in the environment, have generally been discontinued in recent years (*e.g.*, chlordane after 1988 and toxaphene after 1986; Bidleman *et al.* 1998a). OCLs have been replaced by two classes of pesticides (organophosphorus and carbamates) which degrade more rapidly. However, because OCLs are long-lived (*e.g.*, dieldrin may have a half-life in excess of two decades (Nagami 1997), their residues remain an environmental concern. The presence of OCLs in contemporary sediment samples may also reflect local or regional atmospheric transport of volatilized pesticides which were applied decades ago to agricultural lands (Spencer *et al.* 1996; Nagami 1997; Bidleman *et al.* 1998a; 1998b) as well as runoff from freshly tilled local farmland (Frithsen *et al.* 1995).

PAHs are ring-shaped organic compounds typically associated with the production and combustion of fossil fuels (Eisler 1987). Specific routes to waterways and sediments include atmospheric deposition after incineration, runoff from                      roadways,                      and                      point-source                      discharges

(Hoffman *et al.* 1984; Eisler 1987; Golomb *et al.* 1997; Ianuzzi *et al.* 1997). Runoff and wastewater treatment plant discharges have been specifically cited as the primary sources of PAHs to Tampa Bay (Doyle *et al.* 1985).

PCBs are synthetic hydrocarbons which were developed primarily for use as an insulating fluid in electrical equipment; other uses include dust control (road construction), in pesticides, and in the production of a variety of other materials (Kennish *et al.* 1992). PCB production was halted after 1977 (Kennish *et al.* 1992). PCBs enter waterways and become associated with sediments *via* both point source and non-point source discharges (Kennish *et al.* 1992) as well as atmospheric deposition after incineration (Finley *et al.* 1997). The primary source of PCBs to Tampa Bay remains indeterminate since estimates could only be developed for atmospheric inputs (Frithsen *et al.* 1995).

OCLs, PAHs, and PCBs are of environmental concern because they may be carcinogenic and mutagenic to aquatic life (Eisler 1987; Gassman *et al.* 1994; McCain *et al.* 1996; Finley *et al.* 1997). DDT and its degradation products have been associated with egg thinning in birds and both OCLs and PCBs been linked to reproductive disorders in aquatic animals (Mora 1996; Stahlschmidt-Allner *et al.* 1997). In 1995, OCL contamination of sediments and freshwater fish triggered a health advisory for fish consumption in Collier County, FL (Ross 1995). PCB contamination has affected fisheries in the Great Lakes and the Hudson River/New York Harbor area. Sublethal effects (*e.g.*, altering reproductive success, fecundity, *etc.*) of organic contaminants may also affect the composition and structure of benthic communities (Carman *et al.* 1995; Murdoch *et al.* 1997).

Within Tampa Bay, sediments from the Lower Hillsborough River, portions of Hillsborough Bay (*e.g.*, Ybor Channel), Allen Creek, Cross Bayou Canal, Bayboro Harbor, St. Petersburg Yacht Basin, lower Boca Ciega Bay, Bear Creek, parts of Middle Tampa Bay, and two locations in the Manatee River have been found to be among the most contaminated and/or toxic areas of Tampa Bay (Mote Marine Lab 1984; Long *et al.* 1991; Long *et al.* 1994; Daskalskis & O'Connor 1994; Seal *et al.* 1994; Carr *et al.* 1996). "Hotspots" were typically located proximate to point sources, storm drains, marinas, and canals (Long *et al.* 1991). The least contaminated sites included Safety Harbor, central

and eastern Old Tampa Bay, Big Bayou, Little Bayou, and Bayou Grande (Long *et al.* 1994). Doyle *et al.* (1985) observed that in those areas of Tampa Bay where hydrocarbon contamination was low, the sources were very often biogenic (*i.e.*, derived from plant materials) and not necessarily anthropogenic.

Carr *et al.* (1996) concluded that "the frequency of the [sediment guideline] exceedences and the associated toxicity indicates that the...benthic community may be subject to adverse contaminant-induced impacts at a number of locations throughout Tampa Bay." Note however, that the NOAA studies selected sample locations to represent areas of known or likely contamination (Long *et al.* 1994). A consequence of this sample design was that 70% to 80% of NOAA's study area was determined to be impacted (Carr *et al.* 1996). Estimates of sediment toxicity for all classes (metals, OCLs, PAHs, PCBs) ranged, depending upon the bioassay test, from 0.08% to >80% of the 550 km<sup>2</sup> sampled by NOAA (Long *et al.* 1996). When concordance among two bioassays was set as the criterion for toxicity, only 0.1% of Tampa Bay was considered to have toxic sediments (Long *et al.* 1996). Where Tampa Bay sediments were found to be toxic, they were characterized by high concentrations of mixtures of chemicals. OCLs, PAHs, and PCB congeners were all associated with toxicity in bioassays. DDT, endrin, specific PAHs and total PCBs were generally present in the toxic samples at concentrations at least equal to those which had been associated with toxicity in other investigations (Long *et al.* 1994).

The Tampa Bay National Estuary Program (now the Tampa Bay Estuary Program) addressed both ecological and human health risks associated with contaminated sediments in a 1996 study (McConnell *et al.* 1996). McConnell *et al.* (1996) showed that, for Tampa Bay, ecological risks and the potential for human health effects were associated with several metals as well as the OCLs DDT, lindane, heptachlor, and heptachlor epoxide, high molecular weight PAHs (HPAH), the individual PAHs fluoranthene and benzo(a)pyrene, and PCBs. Other Tampa Bay "contaminants of concern" (Frithsen *et al.* 1995) include the OCLs chlordane, dieldrin, endosulfan, and mirex.

The objective of this report is to estimate the areal extents of contamination of Tampa Bay sediments by selected OCLs, PAHs, and PCBs and is to be a companion to the summary of sediment metals contamination previously produced (Grabe 1997). Sampling took place over a four year "baseline" period (1993-1996) but samples collected during 1994 were not analyzed for organic contaminants.

## SECTION II

### MATERIALS & METHODS

#### II.1. STUDY DESIGN

Coastal Environmental, Inc. (1994) designed the benthic/sediment contaminant monitoring program for Tampa Bay after the USEPA's Environmental Monitoring and Assessment Program ["EMAP"] (USEPA 1990). Tampa Bay is stratified (by bay segment; *cf.* Lewis & Whitman 1985); sample locations were selected at random and with known probability within each segment. This design yields approximate unbiased estimates of the various environmental variables measured, as well as unbiased estimators of the standard error of the mean (Coastal Environmental, Inc. 1994).

The mechanics of the study design are outlined in Coastal Environmental, Inc. (1994) and Grabe *et al.* (1996). The seven defined strata are: Old Tampa Bay [OTB], Hillsborough Bay [HB], Middle Tampa Bay [MTB], Lower Tampa Bay [LTB], Boca Ciega Bay [BCB], Terra Ceia Bay [TCB], and the Manatee River [MR]. A hexagonal grid was superimposed over each bay segment and sample locations were randomly selected within each hexagon. The same coordinates were sampled in 1993 and 1994; in 1995, and again in 1996, sample locations were re-randomized for the four main-stem bay segments (OTB, HB, MTB, LTB). In the BCB, TCB, and MR segments, samples were only analyzed for chemical contaminants in 1996.

Data were generally lacking for four tributaries (Hillsborough [HR], Palm [PR], Alafia [AR], and the Little Manatee [LMR] rivers) during this period because the sizes of the hexagons overlaying these tributaries were of such a size that the probability that sampling points would be randomly located in the water is low. To address this shortcoming, specific samples were collected within these tributaries beginning in 1995. For the 1995 sampling, the random grid coordinates overlaying the tributaries were repositioned by adjusting either latitude or longitude so that sampling points were in the water. During 1996, rectangular grids (2.5 km<sup>2</sup>) were superimposed over these tributaries and random x,y coordinates were drawn until sampling points were located within the rivers. This approach yielded between two and five sample locations per year in each of these four tributaries.

All sediment samples were collected during September-October of each year; sample locations for 1993-1996 are shown in Figure 1.

## **II.2. FIELD METHODS**

Sediment samples were collected with a stainless steel Young grab sampler (0.04 m<sup>2</sup>). During 1993 (and 1994) the sampler was cleaned at each station by rinsing with ambient bay water (Courtney *et al.* 1993). Beginning in 1995 and 1996, the sampler was cleaned at each station with Liquinox, rinsed in ambient bay water, and then rinsed again with pesticide grade isopropanol (Courtney *et al.* 1995).

The upper two centimeters of sediment was removed with a Teflon trowel and spooned into a stainless steel beaker. In 1993 these tools were cleaned with ambient bay water before use at each location (Courtney *et al.* 1993). In 1995 and 1996, both implements were cleaned with Liquinox, rinsed in ambient bay water, and then rinsed again with pesticide grade isopropanol (Courtney *et al.* 1995). In practice, two to three grab samples were required to provide enough sediment for the laboratory analyses.

Once a sufficient amount of sediment was collected, the sample was homogenized by thoroughly mixing the contents of the beaker with the trowel. The mixture was then spooned into high density polyethylene jars for trace metals analysis and into 500-ml glass jars (lined with an aluminum foil barrier between the sediment sample and the lid in 1993 and with Teflon lined caps in 1995-1996) for organic analyses. Both containers were chemically cleaned (acid wash) prior to use.

## **II.3. LABORATORY METHODS**

Skidaway Institute of Oceanography (Savannah, GA), courtesy of USEPA-Gulf Breeze, analyzed the 1993 sediment samples using methods described in EPA (1993). QA/QC were after Heitmuller *et al.* (1993).

**Figure 1. Location of sampling stations for sediments in Tampa Bay, 1993-1996**



HCEPC's laboratory analyzed sediment samples for 1995 and 1996 in the main stem bay segments using EPA Method 8080 for OCLs and PCBs and Method 8270 for PAHs. Southern Analytical Laboratory (Oldsmar, FL) analyzed 1996 samples from the BCB, TCB, and MR segments for OCLs using EPA Method 8080. Method detection limits [MDLs] are shown, by year and laboratory, in Table 1.

QA/QC was ensured by the use of standard reference materials (1993), matrix spikes and spiked duplicates. Accuracy was determined by analyzing the reference materials; the requirement was that the results be within 80-120% of the certified values (T. Heitmuller, pers. comm. 19 Mar 1997). Precision was determined by comparing the "relative percent difference" between matrix spike duplicates and matrix duplicates; the criterion was that the average relative percent difference be <30% (T. Heitmuller, pers. comm. 19 Mar 1997).

#### **II.4. DATA ANALYSES**

Contaminant concentrations <MDL (Table 1) were treated as 0.5\*MDL in the data analyses. "Marginal" and "subnominal" sediments were so designated by comparing concentrations of the measured contaminants with the Threshold Effects Level (TEL) and Predicted Effects Level (PEL) concentrations developed by MacDonald Environmental Services, Ltd. (1994) for Florida estuarine sediments (Table 2). Both the TEL and PEL were based upon an assessment of integrated biological and chemical data, including bioassays and field studies. The TEL is defined as the contaminant concentration below which adverse biological effects are never observed. The PEL is defined as the contaminant concentration above which adverse biological effects are likely.

Recent work by NOAA has shown that there is generally a high probability of biological effects when contaminant concentrations exceed the "Effects Range Median" (ERM) (Long *et al.* 1995b), a contaminant concentration which is similar to the PEL (Table 2). The likelihood of biological effects is quite low when contaminant concentrations are less than the "Effects Range Low" (ERL) (Long *et al.* 1995b), a contaminant concentration which is similar to the TEL. For example, organic contaminants at concentrations <ERL had biological effects in bioassays between 5% (*pp*DDE) and 27.3%

**Table 1. Summary Method Detection Limits (MDLs) (ppb) of organic contaminants in Tampa Bay sediments, 1993 & 1995-1996.**

| CONTAMINANT                                | 1993   | 1995 | 1996 (HCEPC) | 1996 (Southern Analytical Lab) |
|--|--------|------|--------------|--------------------------------|
| <b>A. Organochlorine Pesticides</b>        |        |      |              |                                |
| Aldrin                                     | 0.35   | 0.6  | 0.6          | 1.0                            |
| Chlordane (Total)                          |        | 5.0  |              |                                |
| a-Chlordane                                |        |      | 0.5          | 1.0                            |
| g-Chlordane                                |        |      | 0.5          |                                |
| Dieldrin                                   | 0.35   | 0.9  | 0.9          | 1.0                            |
| DDT  |        | 0.5  | 0.5          | 1.0                            |
| DDD  |        | 0.2  | 0.2          | 1.0                            |
| DDE  |        | 1.1  | 1.1          | 1.0                            |
| ppDDT                                      | 0.35   |      |              | 1.0                            |
| ppDDD                                      | 0.35   |      |              | 1.0                            |
| ppDDE                                      | 0.35   |      |              | 1.0                            |
| Endosulfan Sulfate                         |        | 0.5  | 0.5          | 1.0                            |
| Endosulfan I                               | 0.35   | 1.9  | 1.9          |                                |
| Endosulfan II                              | 0.35   | 0.1  | 0.1          |                                |
| Endrin                                     | 0.35   | 0.3  | 0.3          | 1.0                            |
| Heptachlor                                 | 0.35   | 3.0  | 3.0          | 1.0                            |
| Heptachlor epoxide                         |        |      |              | 1.0                            |
| Hexachlorobenzene                          |        |      |              | 1.0                            |
| Lindane                                    | 0.35   | 0.6  | 0.6          | 1.0                            |
| Mirex                                      |        | 1.0  | 0.5          | 1.0                            |
| Toxaphene                                  | 0.35   | 0.4  | 0.4          | 20.0                           |
| Trans-Nonachlor                            |        |      |              | 1.0                            |
| <b>B. Polycyclic Aromatic Hydrocarbons</b> |        |      |              |                                |
| Acenaphthene                               | 0.0102 | 22.0 | 22.0         |                                |
| Acenaphthylene                             | 0.0048 | 22.0 | 22.0         |                                |
| Anthracene                                 | 0.0038 | 20.0 | 20.0         |                                |
| Benz(a)anthracene                          | 0.0044 | 21.0 | 21.0         |                                |
| Benzo(a)pyrene                             | 0.0088 |      |              |                                |
| Benzo(b)pyrene                             |        | 30.0 | 30.0         |                                |
| Benzo(g)pyrene                             |        | 24.0 | 24.0         |                                |
| Benzo(k)pyrene                             |        | 19.0 | 19.0         |                                |
| Chrysene                                   |        | 22.0 | 22.0         |                                |
| Dibenz(a,h)anthracene                      | 0.0074 | 22.0 | 22.0         |                                |
| Fluoranthene                               |        | 26.0 | 26.0         |                                |
| Fluorene                                   | 0.005  |      |              |                                |
| Indenopyrene                               |        | 17.0 | 17.0         |                                |
| 2-methylnapthalene                         | 0.0099 |      |              |                                |
| Napthalene                                 | 0.0099 | 16.0 | 16.0         |                                |
| Perylene                                   | 0.0038 |      |              |                                |
| Phenanthrene                               |        | 20.0 | 20.0         |                                |
| Pyrene                                     |        |      |              |                                |
| <b>C. Polychlorinated Biphenyls</b>        |        |      |              |                                |
| PCBs- individual congeners                 |        | 0.35 |              |                                |
| PCBs-individual arochlors                  |        |      | 10.0         | 2.5                            |

**Table 2. Summary of TEL<sup>a</sup>, ERL<sup>b</sup>, PEL<sup>a</sup>, and ERM<sup>b</sup> concentrations (ppb) of organic contaminants.**

| CONTAMINANT                                    | TEL    | ERL    | PEL     | ERM     |
|--|--------|--------|---------|---------|
| <b>A. Organochlorine Pesticides</b>            |        |        |         |         |
| Chlordane                                      | 2.26   | 0.50   | 4.79    | 6.00    |
| Dieldrin                                       | 0.72   | 0.02   | 4.30    | 8.00    |
| Total DDT                                      | 3.89   | 1.58   | 51.70   | 46.10   |
| Lindane  | 0.32   | ----   | 0.99    | -----   |
|  |        |        |         |         |
| <b>B-1. Low Molecular Weight PAHs (LPAHs)</b>  |        |        |         |         |
| Acenaphthene                                   | 6.71   | 16.0   | 88.9    | 500.0   |
| Acenaphthylene                                 | 5.87   | 44.0   | 128.0   | 640.0   |
| Anthracene                                     | 46.9   | 85.3   | 245.0   | 1100.0  |
| Fluorene                                       | 21.2   | 19.0   | 144.0   | 540.0   |
| 2-methylnaphthalene                            | 20.2   | 70.0   | 201.0   | 670.0   |
| Phenanthrene                                   | 86.7   | 240.0  | 544.0   | 1500.0  |
| Total LPAHs                                    | 312.0  | 552.0  | 1442.0  | 3160.0  |
|  |        |        |         |         |
| <b>B-2. High Molecular Weight PAHs (HPAHs)</b> |        |        |         |         |
| Benz(a)anthracene                              | 74.8   | 261.0  | 693.0   | 1600.0  |
| Benzo(a)pyrene                                 | 88.8   | 430.0  | 763.0   | 1600.0  |
| Chrysene                                       | 108.0  | 384.0  | 846.0   | 2800.0  |
| Dibenz(a,h)anthracene                          | 6.22   | 63.4   | 135.0   | 260.0   |
| Fluoranthene                                   | 113.0  | 600.0  | 1494.0  | 5100.0  |
| Pyrene   | 153.0  | 665.0  | 1398.0  | 2600.0  |
| Total HPAHs                                    | 655.0  | 1700.0 | 6676.0  | 9600.0  |
|  |        |        |         |         |
| <b>B-3. Total PAHs</b>                         | 1684.0 | 4022.0 | 16770.0 | 44792.0 |
|  |        |        |         |         |
| <b>C. Polychlorinated Biphenyls</b>            |        |        |         |         |
| Total PCBs                                     | 21.6   | 22.7   | 189.0   | 180.0   |

<sup>a</sup> after MacDonald Environmental Services, Ltd. (1994)

<sup>b</sup> after Long & Morgan (1990)

observed between 50% (*pp*DDE) and 100% of the time (Acenaphthylene, 2-methylnaphthalene, and low molecular weight PAHs [LPAHs]) (Long *et al.* 1995).

Another approach to identifying contaminated sediments is to compute the ratios of individual contaminant concentrations to their PEL (or ERM) and then average these over all contaminants or over a class of contaminants (PEL quotient). The specific composition of a PEL must be accurately described since all sediment quality monitoring programs do not necessarily include a common suite of variables.

For example, in a California study, Fairey (1998) reported that PEL quotients based upon a subset of contaminants were better predictors than a PEL quotient based upon all measured contaminants. Similarly, Swartz (1998) observed that a summary PEL quotient for PAHs may be more meaningful than PEL quotients for individual PAHs since toxicity is often a consequence of the mixture of PAH species.

For this study separate PEL quotients were calculated for OCLs, PAHs (LPAHs, HPAHs, total PAHs), and total PCBs. The components of the PEL quotient for each class of contaminants is:

- a. Pesticides: chlordane ( $\alpha$ + $\gamma$ -chlordane), dieldrin, lindane, total DDT  
(=DDT+DDD+DDE+*pp*DDT+*pp*DDD+*pp*DDE);
- b. LPAHs: acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, 2-methylnaphthalene, and phenanthrene;
- c. HPAHs: benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, and pyrene;
- d. Total PAHs: LPAHs + HPAHs;
- e. Total PCBs-1993: Total of congeners 08, 18, 28, 29, 44, 52, 66, 77, 87, 101, 105, 118, 126, 128, 138, 153, 170, 180, 187, 195, 200, 206, and 209;
- f. Total PCBs-1995 & 1996: Total of Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1264.

Sediments were designated as "healthy" if a contaminant concentration was less than the TEL or if a PEL quotient was  $\leq 0.1$ . Sediments were "marginal" if a contaminant concentration exceeded the TEL and was less than the PEL or if a PEL quotient was  $0.1 < \text{PEL quotient} < 1.0$ . Sediments were

designated as "subnominal" or "degraded" if a contaminant concentration exceeded the PEL or if a PEL quotient was >1.0. Additionally, for Tampa Bay, a PEL quotient of 1.6 has been proposed as an Assessment Target (MacDonald 1997).

Two PAH ratios have been advanced as interpretive tools for identifying possible source(s) of PAH contamination (Mastran *et al.* 1994). The ratios are the Phenanthrene:Anthracene (P:A) ratio and the Fluoranthene:Pyrene (F:P) ratio. Each ratio is expected to be lower (P:A<11; F:P 0.95-1.4) in urban areas where runoff may be the predominant source of PAHs and higher (P:A>11; F:P 1.2-1.7) where atmospheric deposition predominates.

Cumulative distribution functions were plotted, by bay segment and tributary subsegment for the various contaminants and composite contaminant totals (*e.g.*, individual pesticides, individual PAHs, HPAHs and LPAHs, total PCBs) as well as the PEL quotient for each class of contaminants. These data reductions facilitate estimation of areal extents of "healthy", "marginal", and "degraded" Tampa Bay sediments.

## SECTION III

### RESULTS

#### III.1 STATUS OF THE INDIVIDUAL BAY SEGMENTS

**III.1.1. Old Tampa Bay:** Approximately 2% (1.5 mi<sup>2</sup>) of OTB sediments were contaminated by the pesticides DDT and chlordane (Figure 2). The most frequently occurring pesticide, endrin, was detected at 30% of the stations; there are no sediment quality assessment guidelines [SQAGs] for endrin. With respect to other pesticides, concentrations were generally below the MDL, although the composite PEL quotient for pesticides was >0.1 for almost 75% (58 mi<sup>2</sup>) of OTB (Figure 3). The mean pesticide PEL quotient for OTB was the highest ranked of the four main bay segments (Figure 4) because of the concentrations of chlordane and DDT at a single location in Culbreath Bayou.

Only low levels of PAH contamination were observed in OTB (Table 3; Figures 3, 5, 6, and 7) and PEL quotients were always <0.1. P:A ratios were generally <10 and F:P ratios <1 (except in samples with PAHs<MDL) suggesting that "runoff" is the primary contributor to PAHs to OTB (Figure 8). PCB concentrations were also uniformly low or <MDL (Table 3; Figure 3).

**III.1.2. Hillsborough Bay:** Approximately 6.6% (2.6 mi<sup>2</sup>) of HB sediments were of marginal quality with respect to DDT contamination and almost 5% (2 mi<sup>2</sup>) was subnominal with respect to chlordane (Figure 9). DDT was the most frequently occurring OCL in HB, having been detected in 49% of the samples. The overall PEL quotient for pesticides indicated that almost 90% of HB sediments were at least "marginally" impacted by pesticides (Figure 10) and the mean PEL quotients for chlordane and total pesticides were within the "marginal" range (Figure 4).

More than five percent of HB sediments were of "marginal" quality with respect to individual PAHs (Figures 9, 11, and 12); none of HB was "subnominal". The PEL quotient for total PAHs showed that 3.4% (1.4 mi<sup>2</sup>) of HB was of at least "marginal" quality. The majority of sediments had low P:A (<10) and F:P ratios (<1 except at sites where concentrations were <MDL) suggesting that runoff is the primary source of PAHs to Hillsborough Bay (Figure 13).

Figure 2. Cumulative proportions of organochlorine pesticide concentrations (ppb) in the Old Tampa Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely. TELs and PELs are not defined for Aldrin, Endosulfan Sulfate, Endrin, or Toxaphene.

**Table 3. Summary of mean OCL pesticide, PAH, and PCB concentrations (ppb): by bay segment. Tampa Bay, 1993 & 1995-1996.**

**A. Organochlorine Pesticides [OCLs]**

|     | ALDR | CHLD    | DDT   | DIEL | ENDSO4 | ENDO-I | ENDO-II | ENDRIN | HEPTA | LIND  | TOXA |
|-----|------|---------|-------|------|--------|--------|---------|--------|-------|-------|------|
| OTB | 0.28 | 4.03*   | 1.36  | 0.37 | 0.26   | 0.70   | 0.12    | 0.35   | 1.08  | 0.26  | 0.18 |
| HB  | 0.29 | 2.20    | 1.82  | 0.45 | 0.27   | 0.96   | 0.09    | 0.20   | 1.40  | 0.29  | 0.20 |
| HR  | 1.28 | 29.62** | 3.98* | 0.51 | 0.75   | 1.38   | 0.49    | 0.79   | 1.50  | 0.38* | 0.38 |
| PR  | 0.30 | 4.76*   | 5.28* | 0.45 | 0.30   | 0.95   | 0.05    | 0.15   | 1.42  | 0.30  | 0.20 |
| AR  | 0.30 | 2.20    | 1.41  | 0.45 | 0.25   | 0.95   | 0.43    | 0.15   | 1.36  | 0.30  | 0.20 |
| MTB | 0.28 | 1.04    | 0.96  | 0.37 | 0.26   | 0.71   | 0.14    | 0.26   | 1.10  | 0.28  | 0.22 |
| LMR | 0.30 | 0.62    | 1.14  | 0.45 | 0.26   | 0.95   | 0.14    | 0.15   | 1.50  | 0.35* | 0.20 |
| LTB | 0.27 | 1.17    | 0.84  | 0.40 | 0.26   | 0.74   | 0.11    | 0.28   | 1.15  | 0.29  | 0.19 |
| BCB | <MDL | <MDL    | <MDL  | <MDL | <MDL   | NA     | NA      | <MDL   | <MDL  | <MDL  | <MDL |
| TCB | <MDL | <MDL    | <MDL  | <MDL | <MDL   | NA     | NA      | <MDL   | <MDL  | <MDL  | <MDL |
| MR  | <MDL | <MDL    | <MDL  | <MDL | <MDL   | NA     | NA      | <MDL   | <MDL  | <MDL  | <MDL |

\*>TEL \*\*>PEL NA= not analyzed MDL= method detection limit

ALD=Aldrin; CHLD=Total Chlordane; DDT=Total DDTs; DIEL=Dieldrin; ENDSO4=Endosulfan Sulfate; ENDOI=Endosulfan I; ENDOII= Endosulfan II; ENDRIN=Endrin; HEPT=Heptachlor; LIND=Lindane; TOXA=Toxaphene

**B-1. Low Molecular Weight PAHs [LPAHs]**

|     | ACENAP  | ACENTHY | ANTHRAC | FLUOR   | NAPTH | 2METHYL | PHENANT  |
|-----|---------|---------|---------|---------|-------|---------|----------|
| OTB | 7.4*    | 7.6*    | 7.0     | 7.7     | 5.4   | <0.1    | 8.7      |
| HB  | 11.4*   | 13.2*   | 12.7    | 11.6    | 12.6  | <0.1    | 32.7     |
| HR  | 157.5** | 30.2*   | 597.5** | 170.9** | 76.0* | NA      | 3586.6** |
| PR  | 11.0*   | 26.4*   | 15.6    | 11.5    | 21.6  | NA      | 74.2     |
| AR  | 11.0*   | 11.0*   | 10.0    | 11.5    | 8.0   | NA      | 15.7     |
| MTB | 7.7*    | 7.7*    | 7.0     | 8.1     | 5.7   | 0.3     | 9.5      |
| LMR | 11.0*   | 11.0*   | 23.0    | 11.5    | 8.0   | NA      | 15.2     |
| LTB | 8.0*    | 8.0*    | 7.2     | 8.3     | 5.8   | <0.1    | 8.8      |
| BCB | NA      | NA      | NA      | NA      | NA    | NA      | NA       |
| TCB | NA      | NA      | NA      | NA      | NA    | NA      | NA       |
| MR  | NA      | NA      | NA      | NA      | NA    | NA      | NA       |

\*>TEL \*\*>PEL NA= not analyzed

ACENAP=Acenaphthene; ACENTHY=Acenaphthylene; ANTHRAC=Anthracene; FLUOR=Fluorene; NAPTH=Naphthalene; 2METHYL=2-Methylnaphthalene; PHENANT=Phenanthrene



**Table 3. Summary of mean OCL pesticide, PAH, and PCB concentrations (ppb): by bay segment. Tampa Bay, 1993 & 1995-1996 (Continued).**

**B-2. High Molecular Weight PAHs [HPAHs]**

|     | BENZ(A)A | BENZO(A)P | CHRY     | DIBENZ | FLUORANT | PYRENE  |
|-----|----------|-----------|----------|--------|----------|---------|
| OTB | 8.8      | <0.1      | 9.4      | 8.2*   | 11.1     | 11.0    |
| HB  | 30.3     | <0.1      | 36.4     | 15.7*  | 59.0     | 64.6    |
| HR  | 2973.2** | NA        | 4400.4** | 915**  | 7540.9** | 6261.5* |
| PR  | 119.6*   | NA        | 187.8*   | 61.8*  | 267.0*   | 317.6*  |
| AR  | 27.4     | NA        | 34.4     | 14.4*  | 45.5     | 46.8    |
| MTB | 9.8      | 1.1       | 11.2     | 8.8*   | 13.2     | 12.2    |
| LMR | 51.1     | NA        | 78.8     | 16.0*  | 95.8     | 78.5    |
| LTB | 7.8      | <0.1      | 8.0      | 8.0*   | 9.7      | 7.7     |
| BCB | NA       | NA        | NA       | NA     | NA       | NA      |
| TCB | NA       | NA        | NA       | NA     | NA       | NA      |
| MR  | NA       | NA        | NA       | NA     | NA       | NA      |

\*>TEL \*\*>PEL NA= not analyzed

BENZ(A)A=Benz(a)anthracene; BENZO(A)P=Benzo(a)pyrene; CHRY=Chrysene; DIBENZ=Dibenz(a,h)anthracene;  
FLUORANT=Fluoranthene; PYRENE=Pyrene

**B-3. Total PAHs & Total PCBs**

|     | TOTAL LPAHs | TOTAL HPAHs | TOTAL PAHs | TOTAL PCBs |
|-----|-------------|-------------|------------|------------|
| OTB | 43.7        | 58.3        | 135.0      | 23.0*      |
| HB  | 92.4        | 241.2       | 435.8      | 33.2*      |
| HR  | 4618.8**    | 25712.8**   | 40955.8**  | 164.8*     |
| PR  | 160.3       | 1148.2*     | 1925.1*    | 33.2*      |
| AR  | 67.2        | 202.6       | 383.8      | 30.5*      |
| MTB | 46.0        | 66.8        | 152.1      | 19.6       |
| LMR | 79.8        | 371.4       | 587.8      | 11.9       |
| LTB | 46.1        | 50.0        | 122.9      | 20.6       |
| BCB | NA          | NA          | NA         | NA         |
| TCB | NA          | NA          | NA         | NA         |
| MR  | NA          | NA          | NA         | NA         |

\*>TEL \*\*>PEL NA= not analyzed

OTB= Old Tampa Bay; HB= Hillsborough Bay; HR= Hillsborough River (1995-1996); PR= Palm River (1995-1996); AR= Alafia River (1995-1996); MTB= Middle Tampa Bay; LMR= Little Manatee River (1995-1996); LTB= Lower Tampa Bay; BCB= Boca Ciega Bay (1996); TCB= Terra Ceia Bay (1996); MR= Manatee River (1996)

**Figure 3. Cumulative proportions of composite PEL quotients for organochlorine pesticides, PAHs, and PCBs in the Old Tampa Bay segment, 1993 & 1995-1996. PEL quotients  $<0.1$  demarcate sediments which have a low probability of toxicity; PEL quotients  $>0.1<1.0$  demarcate sediments of "marginal" quality.**

**Figure 4. Mean PEL quotients for the organochlorine pesticides DDT, Chlordane, Dieldrin, and Total OCL pesticides (DDT+Chlordane+Dieldrin+Lindane), by bay segment, 1993 & 1995-1996.**

**Figure 5. Cumulative proportions of low molecular weight PAH concentrations in the Old Tampa Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 6. Cumulative proportions of high molecular weight PAH and total PAH concentrations in the Old Tampa Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 7. Mean PEL quotients for total PAHs, high molecular weight PAHs, and low molecular weight PAHs, by bay segment, 1993 & 1995-1996.**

**Figure 8. Cumulative proportions of Phenanthrene:Anthracene and Fluorene:Pyrene ratios in the Old Tampa Bay segment, 1993 & 1995-1996. Horizontal lines demarcate the lower and upper quartiles.**

**Figure 9. Cumulative proportions of organochlorine pesticide concentrations (ppb) in the Hillsborough Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely. TELs and PELs are not defined for Aldrin, Endosulfan Sulfate, Endrin, or Toxaphene.**



**Figure 10. Cumulative proportions of composite PEL quotients for organochlorine pesticides, PAHs, and PCBs in the Hillsborough Bay segment, 1993 & 1995-1996. PEL quotients  $<0.1$  demarcate sediments which have a low probability of toxicity; PEL quotients  $>0.1<1.0$  demarcate sediments of "marginal" quality.**

**Figure 11. Cumulative proportions of low molecular weight PAH concentrations in the Hillsborough Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 12. Cumulative proportions of high molecular weight PAH and total PAH concentrations in the Hillsborough Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 13. Cumulative proportions of Phenanthrene:Anthracene and Fluorene:Pyrene ratios in the Hillsborough Bay segment, 1993 & 1995-1996. Horizontal lines demarcate the lower and upper quartiles.**

Total PCBs exceeded the PEL at a single station (the 1995 sample near Port Sutton). Based upon the PEL quotient (Figure 10), approximately 27% (11 mi<sup>2</sup>) of HB sediments were at least marginally contaminated by PCBs.

III.1.2.1 Lower Hillsborough River: Eight samples were analyzed for sediment contaminants in the Lower Hillsborough River proper during 1995 and 1996. OCL concentrations were generally higher in the Lower Hillsborough River than in any other segment or subsegment of Tampa Bay (Table 3; Figure 4). Chlordane concentrations in the Lower Hillsborough River were above the PEL in three of the eight samples, including one location with a concentration of 160 ppb (>30 times the PEL); DDT concentrations were >TEL at these same three sites (Figure 14). These data are preliminary and suggest that >75% of the Lower Hillsborough River sediments may be contaminated by OCLs (Figure 15).

Lower Hillsborough River sediments were also more contaminated by PAHs than any other segment or subsegment of Tampa Bay (Table 3; Figure 7). Three-quarters of the sites sampled also had total PAH concentrations >TEL, and, in the 1996 sample under I-275, the concentration was in excess of 160,000 ppb (Figures 16 and 17). Both HPAHs and LPAHs exceeded their PELs at five of the eight sites. The PEL quotients for PAHs were >1 at six of the eight sites. The majority of sediment samples had low P:A and F:P ratios suggesting runoff is the primary source of PAHs to the Lower Hillsborough River (Figure 18).

The PEL ratio for total PCBs exceeded 0.1 at six sites and was >1.0 at three of the sites (Figure 14).

III.1.2.2 Palm River: Five samples, two in 1995 and three in 1996, were analyzed for sediment contaminants. Palm River sediments were ranked second to the Lower Hillsborough River in overall pesticide contamination (Table 3; Figure 4). Chlordane concentrations at one site exceeded the PEL and at two other sites exceeded the TEL; at these same three sites the TEL was exceeded for DDT (Figure 19). The PEL quotients for total OCLs were all indicative of "marginal" sediment quality (Figure 20).

**Figure 14. Cumulative proportions of organochlorine pesticide concentrations (ppb) in the Lower Hillsborough River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely. TELs and PELs are not defined for Aldrin, Endosulfan Sulfate, Endrin, or Toxaphene.**

**Figure 15. Cumulative proportions of composite PEL quotients for organochlorine pesticides, PAHs, and PCBs in the Lower Hillsborough River subsegment, 1995-1996. PEL quotients  $<0.1$  demarcate sediments which have a low probability of toxicity; PEL quotients  $>0.1<1.0$  demarcate sediments of "marginal" quality.**

**Figure 16. Cumulative proportions of low molecular weight PAH concentrations in the Lower Hillsborough River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**



**Figure 17. Cumulative proportions of high molecular weight PAH and total PAH concentrations in the Lower Hillsborough River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 18. Cumulative proportions of Phenanthrene:Anthracene and Fluorene:Pyrene ratios in the Lower Hillsborough River subsegment, 1995-1996. Horizontal lines demarcate the lower and upper quartiles.**

**Figure 19. Cumulative proportions of organochlorine pesticide concentrations (ppb) in the Palm River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely. TELs and PELs are not defined for Aldrin, Endosulfan Sulfate, Endrin, or Toxaphene.**

**Figure 20. Cumulative proportions of composite PEL quotients for organochlorine pesticides, PAHs, and PCBs in the Palm River subsegment, 1995-1996. PEL quotients <0.1 demarcate sediments which have a low probability of toxicity; PEL quotients >0.1<1.0 demarcate sediments of "marginal" quality.**

None of the individual PAH concentrations or any of the composite measures exceeded the PEL for individual PAHs although TELs were generally exceeded for specific PAHs in three of the five samples (Figures 20, 21 and 22). The majority of sediments had low P:A and F:P ratios (Figure 23) suggesting runoff is the primary source of PAHs to the Palm River. PCB PEL quotients were  $>0.1<1.0$  at two of the sites (Figure 20).

**III.1.2.3 Alafia River:** Eleven samples were analyzed for organic contaminants during 1995-1996. Chlordane was the only pesticide whose concentrations exceeded either the PEL (one site) or the TEL (one site excluding three sites with a MDL>TEL) (Figure 24). All sites had a composite pesticide PEL $>0.1$  (Figure 25), although MDLs were  $>TEL$  at three of these sites.

PAH concentrations were generally  $<TEL$  (Figure 26 and 27); the composite PEL quotient for PAHs was  $<0.1$  (Figure 25) indicating that PAH contamination was not evident in the samples collected to date from the Alafia River. The majority of sediments had low P:A and F:P ratios suggesting, again, that runoff is the primary source of PAHs to the Alafia River (Figure 28).

PCB concentrations were also quite low and at sites with PEL quotients  $>0.1$  this was generally a function of the MDL $>TEL$  (Figure 25).

**III.1.3. Middle Tampa Bay:** Lindane and DDT concentrations exceeded the TEL in 6% and 1.5%, respectively, of the MTB segment sediments (Figure 29). Endrin was the most widespread pesticide in this bay segment, detectable in at least 31% of the samples. The composite PEL quotient for OCLs was  $>0.1$  at almost 75% of MTB (Figure 30), although "high" MDLs biased this estimate.

PAH contaminated sediments were rarely encountered in MTB, being restricted to low frequencies of only a few individual PAHs (Figures 31 and 32); total PAH concentrations exceeded the TEL at only one location (Figures 30 and 32). Those sites with PAH concentrations  $>MDL$  had low P:A and F:P ratios (Figure 33) suggesting runoff is a major source of PAHs to MTB. The PEL quotient for PCBs exceeded 0.1 at only a single site (excluding samples with high MDLs) (Figure 30).

**Figure 21. Cumulative proportions of low molecular weight PAH concentrations in the Palm River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 22. Cumulative proportions of high molecular weight PAH and total PAH concentrations in the Palm River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 23. Cumulative proportions of Phenathrene:Anthracene and Fluorene:Pyrene ratios in the Palm River subsegment, 1995-1996. Horizontal lines demarcate the lower and upper quartiles.**



**Figure 24. Cumulative proportions of organochlorine pesticide concentrations (ppb) in the Alafia River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely. TELs and PELs are not defined for Aldrin, Endosulfan Sulfate, Endrin, or Toxaphene.**

**Figure 25. Cumulative proportions of composite PEL quotients for organochlorine pesticides, PAHs, and PCBs in the Alafia River subsegment, 1995-1996. PEL quotients  $<0.1$  demarcate sediments which have a low probability of toxicity; PEL quotients  $>0.1<1.0$  demarcate sediments of "marginal" quality.**

**Figure 26. Cumulative proportions of low molecular weight PAH concentrations in the Alafia River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 27. Cumulative proportions of high molecular weight PAH and total PAH concentrations in the Alafia River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 28. Cumulative proportions of Phenathrene:Anthracene and Fluorene:Pyrene ratios in the Alafia River subsegment, 1995-1996. Horizontal lines demarcate the lower and upper quartiles.**

**Figure 29. Cumulative proportions of organochlorine pesticide concentrations (ppb) in the Middle Tampa Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely. TELs and PELs are not defined for Aldrin, Endosulfan Sulfate, Endrin, or Toxaphene.**

**Figure 30. Cumulative proportions of composite PEL quotients for organochlorine pesticides, PAHs, and PCBs in the Middle Tampa Bay segment, 1993 & 1995-1996. PEL quotients  $<0.1$  demarcate sediments which have a low probability of toxicity; PEL quotients  $>0.1<1.0$  demarcate sediments of "marginal" quality.**

**Figure 31. Cumulative proportions of low molecular weight PAH concentrations in the Middle Tampa Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**



**Figure 32. Cumulative proportions of high molecular weight PAH and total PAH concentrations in the Middle Tampa Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 33. Cumulative proportions of Phenathrene:Anthracene and Fluorene:Pyrene ratios in the Middle Tampa Bay segment, 1993 & 1995-1996. Horizontal lines demarcate the lower and upper quartiles.**

**III.1.3.1 Little Manatee River:** OCL concentrations were either low (<PEL) or <MDL in the Little Manatee River (Figures 34 and 35). Lindane was detected at one location at a concentration >TEL.

PAH concentrations were also generally "low" or <MDL (Figures 35, 36, and 37), although PAH concentrations >TEL were measured at a site just downstream of I-75. P:A ratios were affected by "high" MDLs; F:P ratios were <1.5, again suggesting runoff is the source of PAHs (Figure 38).

**III.1.4. Lower Tampa Bay:** Three OCLs were detected at concentrations >TEL in LTB: Dieldrin (3.2% of bay segment area), lindane (1.6% of bay segment), and chlordane (1.6% of bay segment area) (Figure 39). Endrin was, again, the most widespread of the pesticides, occurring at 27% of the sites. Overall, approximately 40% of LTB sediments (excluding sites with high MDLs) were of "marginal" quality with respect to total OCLs (Figure 40).

Both PAH and PCB concentrations were uniformly low (Figures 40, 41, and 42) and <TEL (there were cases where the MDL>TEL). PAH ratios were essentially not interpretable since few samples had PAH concentrations >MDL (Figure 43)

**III.1.5. Boca Ciega Bay:** Sediment samples were analyzed for OCLs beginning in 1996; all OCLs were <MDL. Sediment samples were not analyzed for either PAHs or PCBs.

**III.1.6. Terra Ceia Bay:** Sediment samples were analyzed for OCLs beginning in 1996; all OCLs were <MDL. Sediment samples were not analyzed for either PAHs or PCBs.

**III.2.7. Manatee River:** Sediment samples were analyzed for OCLs beginning in 1996; all OCLs were <MDL. Sediment samples were not analyzed for either PAHs or PCBs.

**Figure 34. Cumulative proportions of organochlorine pesticide concentrations (ppb) in the Little Manatee River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely. TELs and PELs are not defined for Aldrin, Endosulfan Sulfate, Endrin, or Toxaphene.**

**Figure 35. Cumulative proportions of composite PEL quotients for organochlorine pesticides, PAHs, and PCBs in the Little Manatee River subsegment, 1995-1996. PEL quotients  $<0.1$  demarcate sediments which have a low probability of toxicity; PEL quotients  $>0.1<1.0$  demarcate sediments of "marginal" quality.**

**Figure 36. Cumulative proportions of low molecular weight PAH concentrations in the Little Manatee River subsegment, 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 37. Cumulative proportions of high molecular weight PAH and total PAH concentrations in the Little Manatee River subsegment 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 38. Cumulative proportions of Phenathrene:Anthracene and Fluorene:Pyrene ratios in the Little Manatee River subsegment, 1995-1996. Horizontal lines demarcate the lower and upper quartiles.**



**Figure 39. Cumulative proportions of organochlorine pesticide concentrations (ppb) in the Lower Tampa Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely. TELs and PELs are not defined for Aldrin, Endosulfan Sulfate, Endrin, or Toxaphene.**

**Figure 40. Cumulative proportions of composite PEL quotients for organochlorine pesticides, PAHs, and PCBs in the Lower Tampa Bay segment, 1993 & 1995-1996. PEL quotients  $<0.1$  demarcate sediments which have a low probability of toxicity; PEL quotients  $>0.1<1.0$  demarcate sediments of "marginal" quality.**

**Figure 41. Cumulative proportions of low molecular weight PAH concentrations in the Lower Tampa Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 42. Cumulative proportions of high molecular weight PAH and total PAH concentrations in the Lower Tampa Bay segment, 1993 & 1995-1996. Vertical lines demarcate the "Threshold Effects Level" [TEL], below which sediments are not considered to be contaminated, and the "Predicted Effects Level" [PEL], above which adverse ecological effects are likely.**

**Figure 43. Cumulative proportions of Phenathrene:Anthracene and Fluorene:Pyrene ratios in the Lower Tampa Bay segment, 1993 & 1995-1996. Horizontal lines demarcate the lower and upper quartiles.**

### **III.2 MAIN- STEM SYNTHESIS: OTB, HB, MTB, & LTB SEGMENTS**

Almost three-quarters of main-stem Tampa Bay sediments were estimated to be at least marginally impacted by pesticides (Table 4; Figures 44, 45 and 46). Marginal concentrations of chlordane and dieldrin were estimated to affect >70% of Tampa Bay sediments. The extremely high areal estimate for marginal degradation by lindane is, in part, an artifact of high MDLs. DDT was much less pervasive.

The composite OCL PEL quotient suggested that only 1% of Tampa Bay sediments were “degraded” during this time period.

Approximately 1% of main-stem Tampa Bay sediments were of "marginal" quality with respect to total PAHs (Table 4; Figure 47); none of these sediments were shown to be “degraded”. Areal extents of contamination by both LPAHs and HPAHs were generally similar.

Almost 40% of main-stem Tampa Bay sediments were marginally contaminated by PCBs (Table 4); high MDLs for PCBs likely inflated this estimate. 0.2% of the bay's sediments were “degraded” by PCBs.

The association between the Tampa Bay Benthic Index [TBBI] (Grabe *et al.* 1996), a measure of the “health” of the animals living in/on Tampa Bay sediments, and the PEL quotients for OCL pesticides and PAHs show that there is a negative association between the TBBI and these PEL quotients (Figure 48). These associations explain only a small fraction (2%-8%) of the total variance. The TBBI appears to be more sensitive to PAH contamination than to OCL contamination since TBBI scores <10 become prevalent at a PAH PEL quotient <0.1 whereas for the composite OCLs relatively low TBBI scores only become prevalent at PEL quotients >0.1. Note that the PEL quotient for composite OCLs is based upon only four pesticides whereas the PEL quotient for PAHs is based upon more than 10 individual PAHs.

**Table 4. Estimates of the percentage of marginal and subnominal sediments for OCL pesticides, total PAHs, LPAHs, HPAHs, and total PCBs: by bay segment. Tampa Bay estuary, 1993 & 1995-1996.**

|                               | OTB   | HB    | MTB   | LTB  | MAIN<br>STEM:<br>TOTAL | BCB     | TCB     | MR      |
|-------------------------------|-------|-------|-------|------|------------------------|---------|---------|---------|
| <b>A. OCL PESTICIDES</b>      |       |       |       |      |                        |         |         |         |
| OCL COMPOSITE:<br>PEL>0.1<1.0 | 68.5  | 91.6  | 70.8  | 73.0 | 73.4                   | 0.0     | 0.0     | 0.0     |
| OCL COMPOSITE:<br>PEL>=1.0    | 1.9   | 1.7   | 0.0   | 0.0  | 0.6                    | 0.0     | 0.0     | 0.0     |
| CHLORDANE<br>PEL>0.1<1.0      | 70.3  | 88.2  | 69.2  | 71.4 | 72.4                   | 0.0     | 0.0     | 0.0     |
| CHLORDANE<br>PEL>=1.0         | 1.9   | 5.1   | 0.0   | 1.6  | 1.5                    | 0.0     | 0.0     | 0.0     |
| TOTAL DDT<br>PEL>0.1<1.0      | 1.9   | 5.0   | 1.5   | 0.0  | 1.6                    | 0.0     | 0.0     | 0.0     |
| TOTAL DDT<br>PEL>=1.0         | 0.0   | 0.0   | 0.9   | 0.0  | 0.3                    | 0.0     | 0.0     | 0.0     |
| TOTAL DIELDRIN<br>PEL>0.1<1.0 | 70.4  | 92.3  | 69.2  | 73.0 | 73.3                   | 0.0     | 0.0     | 0.0     |
| TOTAL DIELDRIN<br>PEL>=1.0    | 0.0   | 0.0   | 0.0   | 0.0  | 0.0                    | 0.0     | 0.0     | 0.0     |
| LINDANE<br>PEL>0.1<1.0        | 100.0 | 100.0 | 100.0 | 98.4 | 99.5                   | 0.0     | 0.0     | 0.0     |
| LINDANE<br>PEL>=1.0           | 0.0   | 0.0   | 0.0   | 1.6  | 0.4                    | 0.0     | 0.0     | 0.0     |
|                               |       |       |       |      |                        |         |         |         |
| <b>B. PAHs</b>                |       |       |       |      |                        |         |         |         |
| TOTAL PAHs<br>PEL>0.1<1.0     | 0.0   | 3.4   | 1.5   | 0.0  | 1.0                    | No Data | No Data | No Data |
| TOTAL PAHs<br>PEL>=1.0        | 0.0   | 0.0   | 0.0   | 0.0  | 0.0                    | No Data | No Data | No Data |
| LPAHs<br>PEL>0.1<1.0          | 0.0   | 8.6   | 1.5   | 0.0  | 1.6                    | No Data | No Data | No Data |
| LPAHs<br>PEL>=1.0             | 0.0   | 0.0   | 0.0   | 0.0  | 0.0                    | No Data | No Data | No Data |
| HPAHs<br>PEL>0.1<1.0          | 0.0   | 6.9   | 1.5   | 0.0  | 1.4                    | No Data | No Data | No Data |
| HPAHs<br>PEL>=1.0             | 0.0   | 0.0   | 0.0   | 0.0  | 0.0                    | No Data | No Data | No Data |
|                               |       |       |       |      |                        |         |         |         |
| <b>C. PCBs</b>                |       |       |       |      |                        |         |         |         |
| TOTAL PCBs<br>PEL>0.1<1.0     | 43.4  | 53.5  | 33.8  | 34.9 | 38.7                   | No Data | No Data | No Data |
| TOTAL PCBs<br>PEL>=1.0        | 0.0   | 1.7   | 0.0   | 0.0  | 0.2                    | No Data | No Data | No Data |

**Figure 44. Map of the distribution of the composite OCL PEL quotients in Tampa Bay, 1993-1996. PEL quotients  $\leq 0.1$  are considered to be "clean"; PEL quotients  $0.1 < \leq 1.0$  represent sediments of "marginal" quality; PEL quotients  $> 1.0$  represent "degraded" sediments.**



**Figure 45. Map of the distribution of chlordane in Tampa Bay, 1993-1996. Concentrations  $<2.25$  ppb are considered to be "clean" ( $<TEL$ ); concentrations  $>2.25 \leq 4.78$  ppb ( $>TEL < PEL$ ) represent sediments of "marginal" quality; concentrations  $>4.79$  ppb ( $>PEL$ ) represent "degraded" sediments.**

**Figure 46. Map of the distribution of DDT in Tampa Bay, 1993-1996. Concentrations  $<3.88$  ppb are considered to be "clean" ( $<TEL$ ); concentrations  $>3.88 \leq 51.69$  ppb ( $>TEL < PEL$ ) represent sediments of "marginal" quality; concentrations  $>51.69$  ppb ( $>PEL$ ) represent "degraded" sediments.**

**Figure 47. Map of the distribution of PEL Quotients for total PAHs in Tampa Bay, 1993-1996. PEL Quotients <0.1 are considered to represent "clean" sediments; PEL Quotients >0.1<1.0 represent sediments of "marginal" quality; PEL Quotients >1.0 represent "degraded" sediments.**

**Figure 48. Association between the Tampa Bay Benthic Index and the PEL quotients for organochlorine pesticides and total PAHs. The linear regression line predicting the relationships is plotted.**

## SECTION IV

### DISCUSSION

Contaminated sediments are of environmental concern because they have been associated with reductions in faunal abundance and numbers of species (Somerfield *et al.* 1994; Hall & Frid 1995; Morrissey *et al.* 1995; Hansen *et al.* 1996), and the proliferation of "pollution tolerant" species (Ward & Hutchings 1996). Sediment contamination to the extent that biological community structure and function is altered could modify the trophic structure of the community and ultimately could be manifest as changes to higher trophic levels (*e.g.*, fish, birds).

McConnell *et al.* (1996) identified chemical contaminants which were likely to confer both ecological and human health risk in several subareas of Hillsborough Bay, western Old Tampa Bay, Boca Ciega Bay, and portions of Middle Tampa Bay. The potential for ecological risk was noted for the OCLs chlordane, DDT, endrin, heptachlor, and lindane, total HPAHs, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(a)anthracene, and PCBs. Chlordane, DDT, and PAHs were each shown to occur at concentrations likely to affect biotic communities in the Lower Hillsborough River; both DDT and chlordane were also detected at high concentrations in eastern Old Tampa Bay (Culbreath Bayou). Endrin was among the most pervasive OCL in Tampa Bay; there are no sediment quality assessment guidelines for endrin to facilitate interpretation of the measured concentrations.

McConnell *et al.* (1996) concluded that there was potential for human health risk from chlordane and heptachlor *via* consumption of fish from portions of Hillsborough Bay. McCain *et al.* (1996) showed that at least four species of fish (hardhead catfish, red drum, Gulf and longnose killifish) collected from Hillsborough Bay had elevated tissue concentrations of chlordane, DDT, PAHs, and PCBs sufficient to manifest themselves both morphologically and histochemically.

*The data collected for this monitoring program cannot necessarily be extrapolated to make inferences about human health risk.* These data are only suitable for evaluating *ecological* risk. To that end these data permit the estimation of the "baseline" extents of sediment

contamination by OCLs, PAHs, and PCBs from which future trends will be tracked. Additionally, data collected through this program have been useful in identifying "hotspots" of sediment contamination as envisioned in the CCMP for Tampa Bay (TBNEP 1996).

Almost three-quarters of main-stem Tampa Bay sediments were estimated to be at least marginally impacted by pesticides. Only 1% of Tampa Bay sediments were estimated to be "degraded" (*i.e.*, having a high probability of being toxic to aquatic life). Hillsborough Bay is the most contaminated of the seven bay segments. Although the data are quite limited, sediments in the Lower Hillsborough and Palm rivers are each more contaminated by OCLs than Hillsborough Bay proper.

Approximately 1% of main-stem Tampa Bay sediments were of "marginal" quality with respect to total PAHs; none of these sediments were in the "degraded" category. Almost 40% of main-stem Tampa Bay sediments were "marginally" contaminated by PCBs. This estimate must be viewed cautiously since it is likely confounded by both the relatively high MDLs for the individual congeners and aroclors as well as the decision to enter 0.5\*MDL as the concentration when PCBs were not detected at the MDL. 0.2% of main-stem Tampa Bay sediments were estimated to be "degraded" by PCBs and this estimate would not be inflated by high MDLs.

Overall sediment contamination by organic compounds is greater in the Hillsborough Bay segment than in other major areas of Tampa Bay. Within Hillsborough Bay, the Lower Hillsborough, Palm, and Alafia rivers show evidence of greater impairment than Hillsborough Bay proper. The databases for these tributaries are quite sparse and the current assessments must be treated as preliminary. Similarly, the database for Terra Ceia Bay, Manatee River, and Boca Ciega Bay segments as well as the Little Manatee River are also limited with respect to organic contaminants and must await further sampling before any firm conclusions can be drawn.

Generic sources of sediment contamination by OCLs, PAHs, and PCBs can include atmospheric deposition (Windom 1992; Golomb *et al.* 1997), point source discharges (*e.g.*, industrial discharges and storm sewers: Shear *et al.* 1996; Iannuzzi *et al.* 1997), and non-point source runoff (USEPA 1992). Within the Tampa Bay system, Frithsen *et al.* (1995) identified agricultural runoff as a primary entry point for the OCLs chlordane, DDT, endosulfan, and dieldrin. Non-point source runoff (presumably from roadways) is the likely primary source of PAHs to Tampa Bay based upon ratios of fluoranthene : pyrene and phenanthrene : anthracene reported in this study.

The Tampa Bay Benthic Index [TBBI] (Grabe *et al.* 1996) was designed to be a measure of the status or "health" of the biota which live in contact with the sediments. If the TBBI is, in fact, a suitable indicator of benthic habitat status, there should be an association between the TBBI and measures of sediment contamination. The data currently available show that the TBBI declines as PEL quotients for OCL pesticides and PAHs increase. These associations explain only a small fraction (2-8%) of the total variance. The TBBI appears to be more sensitive to PAH contamination than to OCL contamination since TBBI scores <10 become prevalent when the PAH PEL quotient is <0.1, whereas relatively low TBBI scores only become prevalent at PEL quotients >0.1. Note that the PEL quotient for composite OCLs is based upon only four pesticides whereas the PEL quotient for PAHs is based upon more than 10 individual PAHs.

## **SECTION V**

### **RECOMMENDATIONS**

1. Outside funding should be sought to support bioassay analyses, as recommended in MacDonald (1997). Addition of such analyses will be useful identifying the concentrations of contaminant mixtures which are, in fact toxic;

2. The Sediment Quality Triad (Chapman 1990) should be invoked as an interpretive tool should a bioassay database be developed (MacDonald 1997);

3. Sampling has been expanded to include the Hillsborough, Palm, Alafia, and Little Manatee Rivers for the years 1997-2000 to establish "baseline" conditions. Because three of these tributaries are to experience a diminution of freshwater inflow as they become more heavily exploited as sources of drinking water in the near future, a rigorous, long-term monitoring program is desirable to facilitate identification of any alterations in the ecology of these systems. For the years 1998-2000, limited supplemental funding for monitoring these tributaries has been obtained from the Hillsborough River and Alafia River Basin Boards of the SWFWMD. However, efforts should be made to secure adequate funding to support and perhaps expand sampling of these tributaries.



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