

## 4.2 Analyses of Sediment Quality Parameters for New Areas of Study

Status and Trends sediment quality data analyses looked at seven study areas: the Christmas Bay/Bastrop Bayou Complex, Galveston Channel, Lower Houston Ship Channel (below Morgan's Point), Upper Houston Ship Channel (Morgan's Point to Buffalo Bayou), Intracoastal Waterway East, Trinity River and West Bay. TCEQ data were most abundant for the upper and lower portions of the Houston Ship Channel and West Bay. The US Army Corps of Engineers (USACE) collected sediment data in some of these areas during maintenance dredging operations. Whenever possible, the TCEQ data are graphed with the USACE data to provide a comparison between data sets. TCEQ sediment screening levels for the appropriate waterbody type are also displayed to present the reader with a line of reference above which contaminant levels are generally deemed unacceptable.

Some sediment data contain gaps where samples for a given compound may not have been collected in a sub-bay or tributary for several years in a row. Additionally, some annual averages are calculated based on only a few samples collected per area per year. To aid the reader, each trend graph is annotated with the average, minimum, and maximum sample size over all yearly averages. An  $R^2$  value is also included in each graph to aid the reader in determining statistical significance of the trend. The Status and Trends Project does not consider a trend to be statically significant if  $R^2 < 0.25$ . In some instances a trend line may extend through time to point on the graph where the trend falls below the x-axis (zero). This is not meant to infer that the pollutant level will actually fall to that zero level at a given point in time. Rather, trend lines are meant to provide the reader with an idea of the general direction of a trend. Sediment trend graphs not displayed in the following sections can be viewed in Appendix C. A summary of all sediment quality trends is located in Appendix E.

### 4.2.1. Inorganic Compounds

Data regarding the concentrations of inorganic compounds in bottom deposits (sediments) of Galveston Bay were collected by the TCEQ from 1974-2002. The Status and Trends Project analyzed these data for the new study areas. Data sets for some tributaries (the Galveston Channel and the Intracoastal Waterway East) contained less than ten years of data and made trend analysis impractical. The inorganic compounds studied include arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc. Data are reported as mg/kg.

#### ***Arsenic***

In aquatic systems, arsenic occurs primarily in two oxidation states, arsenic (V) and arsenic (III). Arsenic primarily enters bodies of water where mining and smelting operations occur. Other possible sources include natural occurrence, coal-fired power plants and incinerators, use as a wood preservative, and pesticide application on crops such as cotton. Arsenic moves from water and sediment to biofilm (attached bacteria, algae, and associated fine detrital material), and then into the benthic invertebrates. The

bioconcentration of arsenic in aquatic organisms occurs primarily in algae and lower invertebrates, although bottom feeding and predatory fish can accumulate the contaminant. Bottom feeding fish are primarily exposed to arsenic due to the element's tendency to stay in the upper sediment levels indefinitely.

As reported in the Status and Trends 2002 report, annual average arsenic concentrations in sediments of the sub-bays and tributaries of the Galveston Bay estuary exhibited no significant ( $R^2 > 0.25$ ) trends. Of the seven new study areas analyzed in 2003, four had no significant trends and three had insufficient (less than ten years) data to determine a trend (See Table 4.2.1.1).

Table 4.2.1.1. Summary of Annual Trends of Arsenic in Sediment.

<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	No Trend	0.04
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	No Trend	0.01
Upper Houston Ship Channel	No Trend	0.05
Intracoastal Waterway East	Insufficient Data	--
Trinity River	Insufficient Data	--
West Bay	No Trend	0.00

As seen in Figure 4.2.1.1, Arsenic in sediment in the Upper Houston Ship Channel generally remains below the TCEQ tidal stream screening level of 8.99 mg/kg. Exceptions to this were in 1979 and 1992. The USACE data collected in 1987, 1998 and 1999 present averages similar to but slightly lower than the TCEQ annual averages.

As seen in Figure 4.2.1.2, arsenic in sediments of the Lower Houston Ship Channel generally stay below the TCEQ estuarine screening level of 9.61 mg/kg with the exception of annual averages in 1978 and 2002. Again, USACE annual averages are similar to or slightly lower than the TCEQ annual averages.

Figure 4.2.1.1. Annual Average Total Arsenic in Bottom Deposits in the Upper Houston Ship Channel

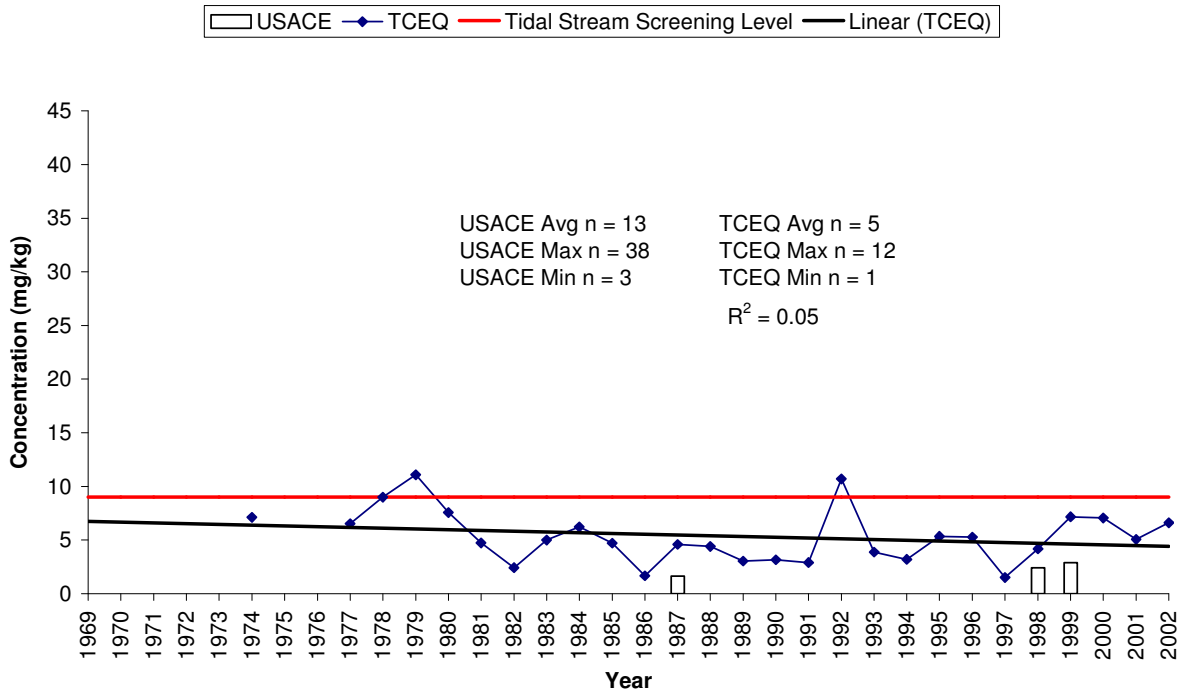
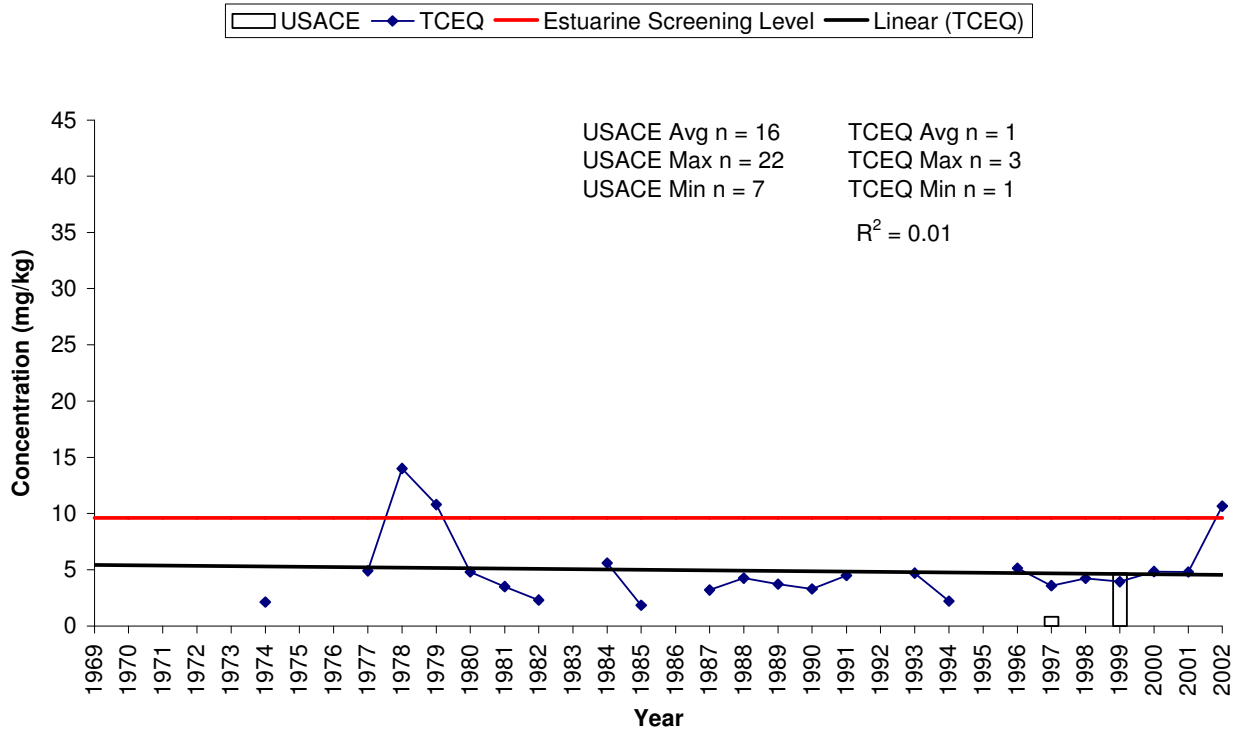


Figure 4.2.1.2. Annual Average Total Arsenic in Bottom Deposits in the Lower Houston Ship Channel



### ***Cadmium***

In water, cadmium can exist as the hydrated ion, or as ionic complexes with other inorganic or organic substances. Cadmium is a relatively mobile metal in aquatic environments and its residence time can be rather long; up to ten years. Cadmium is a parameter of concern due to its ability to be taken up and retained by aquatic and terrestrial plants. In turn, cadmium bioaccumulates in the liver and kidney of animals that consume the plants. Although cadmium can have substantial levels in water and sediment, its concentration in aquatic animals can reach orders of magnitude higher.

As reported in 2002, trends in annual average total cadmium concentrations decline or exhibit no trends across most sub-bays and tributaries of Galveston Bay. Of the seven new study areas, four had insufficient (less than ten years) data (see Table 4.2.1.2). As seen in Figures 4.2.1.3 and 4.2.1.4, two areas exhibited declining trends (the Upper Houston Ship Channel and West Bay). The Trinity River did not have a significant trend.

Table 4.2.1.2. Summary of Annual Trends of Cadmium in Sediment.

<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	Insufficient Data	--
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	Insufficient Data	--
Upper Houston Ship Channel	Declining	0.53 (p < 0.001)
Intracoastal Waterway East	Insufficient Data	--
Trinity River	No Trend	0.07
West Bay	Declining	0.38 (p = 0.002)

The TCEQ Cadmium in Sediment Tidal Stream Screening Level of 0.75 mg/kg was applied to the Upper Houston Ship Channel (Figure 4.2.1.3). Annual averages in the Upper Houston Ship Channel exceeded the screening level throughout the 1970s and 1980s.

Trends from the open bay portions of the Lower Houston Ship Channel were compared to the TCEQ Estuarine Screening Level of 0.663 mg/kg. Annual averages exceeded the screening level in the 1970s and 1980s.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.1.3. Annual Average Total Cadmium in Bottom Deposits in the Upper Houston Ship Channel

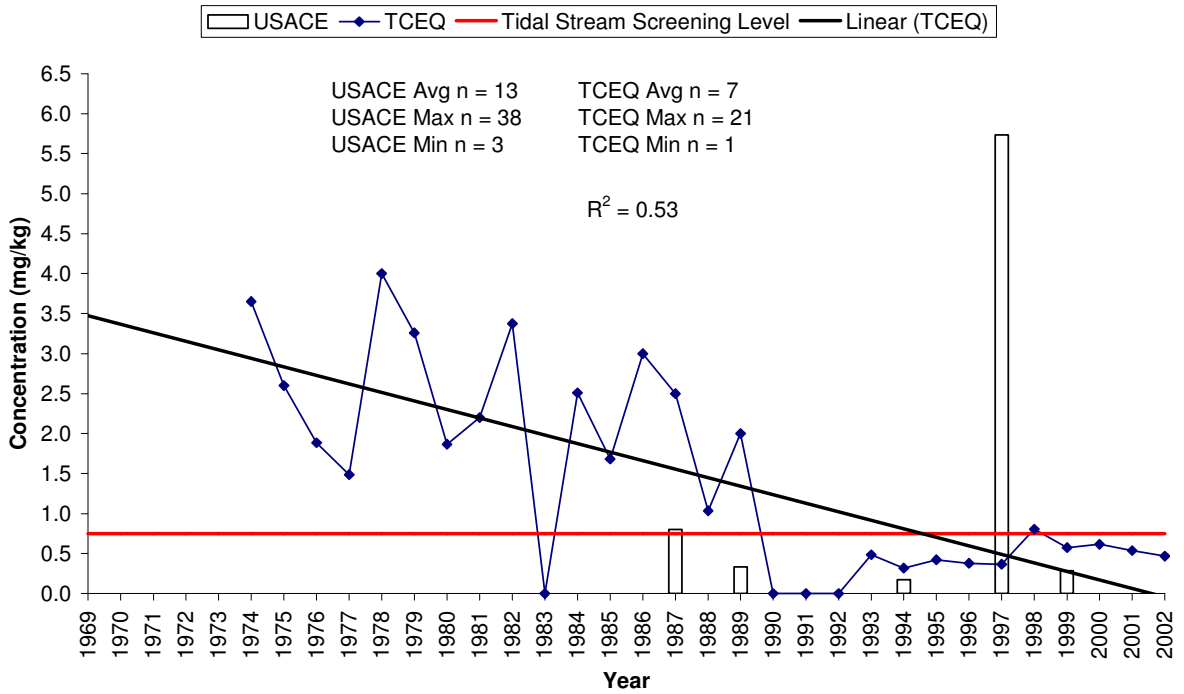
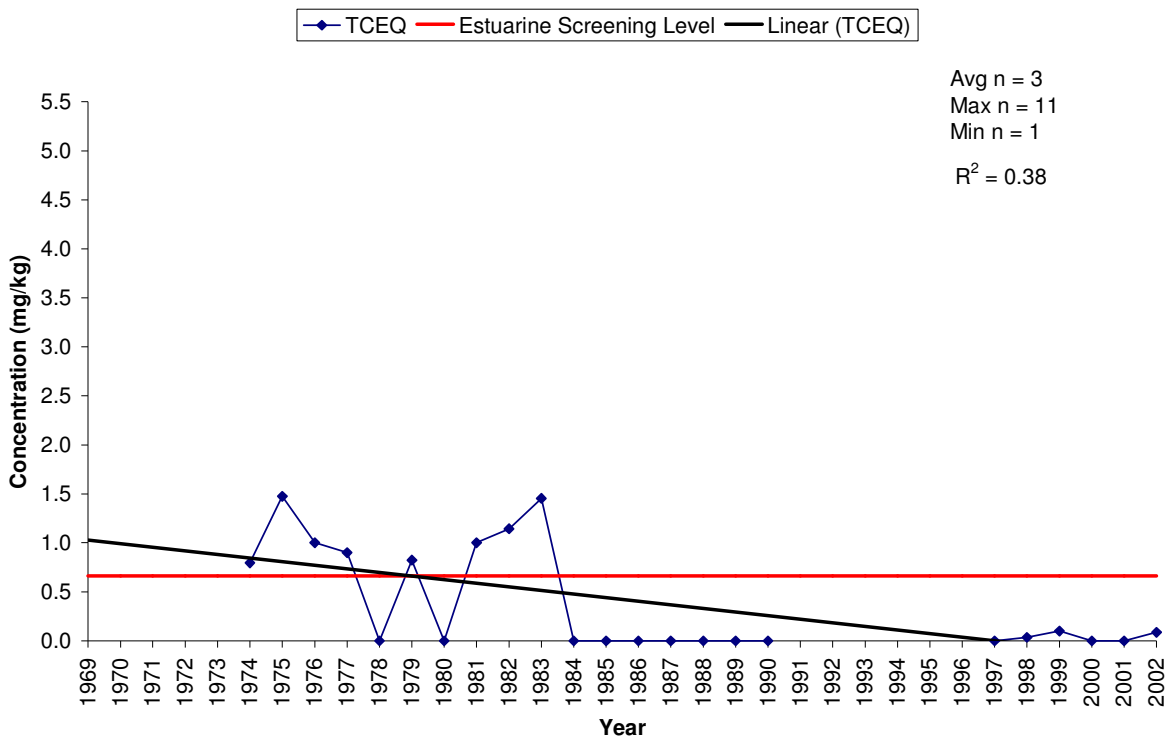


Figure 4.2.1.4. Annual Average Total Cadmium in Bottom Deposits in West Bay



### **Chromium**

The exact chemical forms of chromium in surface waters are not well defined with most forms present as Cr (VI) ( a known carcinogen) and a small amount present as Cr (III) in organic complexes (an essential nutrient). As with most other metals, most of the chromium found in aquatic environments is ultimately deposited in sediments. After deposition or while still present in suspended solids, there is a high potential for bioconcentration of chromium in aquatic organisms. Chromium compounds are also known to be persistent in water.

As reported by the Status and Trends Project in 2002, annual average concentrations of chromium in sediment in most areas of Galveston Bay exhibit no trends or slightly decreasing trends. Of the seven new study areas, the Intracoastal Waterway East and the Galveston Channel lacked sufficient data (less than ten years) to discern a trend. The Christmas Bay/Bastrop Bayou Complex was the only new study area to exhibit a significant trend (Table 4.2.1.3), but data gaps were present.

Table 4.2.1.3. Summary of Annual Trends of Chromium in Sediment.

<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	Decreasing	0.26 (p = 0.129)
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	No Trend	0.02
Upper Houston Ship Channel	No Trend	0.22
Intracoastal Waterway East	Insufficient Data	--
Trinity River	No Trend	0.12
West Bay	No Trend	0.01

Of interest are the trend graphs for the Upper and Lower Houston Ship Channel (Figures 4.2.1.5 and 4.2.1.6). In both portions of the Houston Ship Channel annual averages based on the data supplied by the USACE are very close to or less than the annual averages derived from the TCEQ data. Data from both agencies appear to be in fairly good alignment.

The TCEQ Chromium in Sediment Tidal Stream Screening Level of 49.0 mg/kg was applied to the Upper Houston Ship Channel (Figure 4.2.1.5). Annual averages in the Upper Houston Ship Channel exceeded the screening level in the mid to late 1970s, early 1980s, 1991 and 2002. In 2002, three of the nine chromium samples collected in the Upper Houston Ship Channel exceeded the Tidal Stream Screening Level. The three samples were collected in Patrick (two samples) and Vince Bayous (one sample).

Trends from the open bay portions of the Lower Houston Ship Channel were compared to the TCEQ Estuarine Screening Level of 36.9 mg/kg (Figure 4.2.1.6). Annual averages exceeded the screening level in 1982 and neared it in 2002. In 2002, two chromium samples were collected in the Lower Houston Ship Channel. One sample collected between Smith and Eagle Points exceeded the Screening Level.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.1.5. Annual Average Total Chromium in Bottom Deposits in the Upper Houston Ship Channel

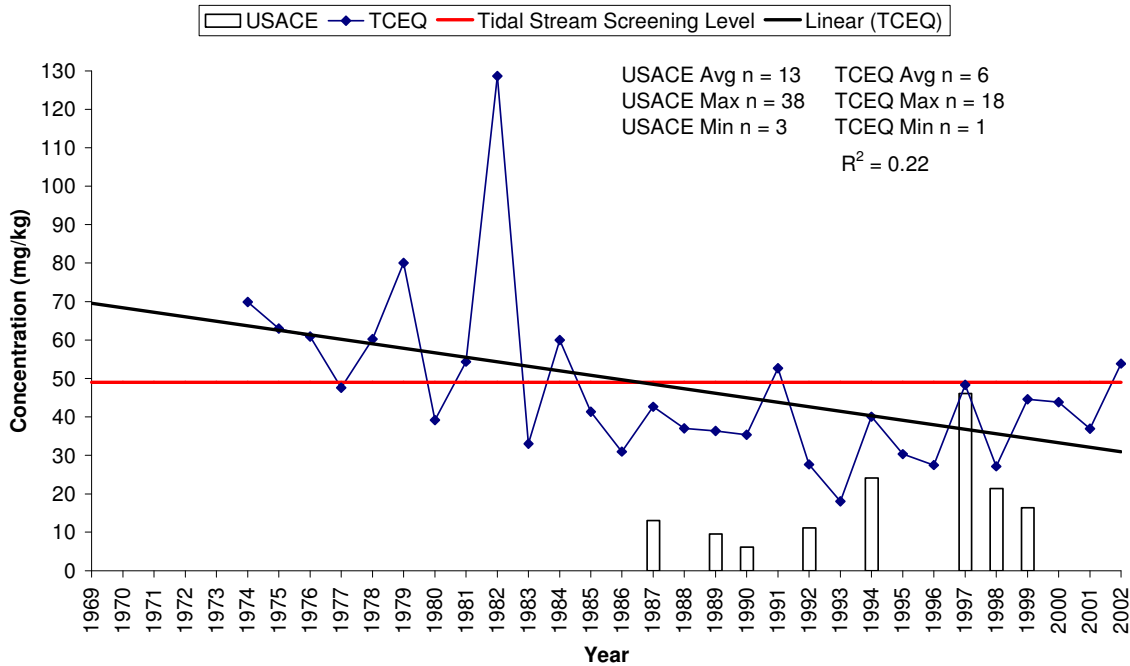
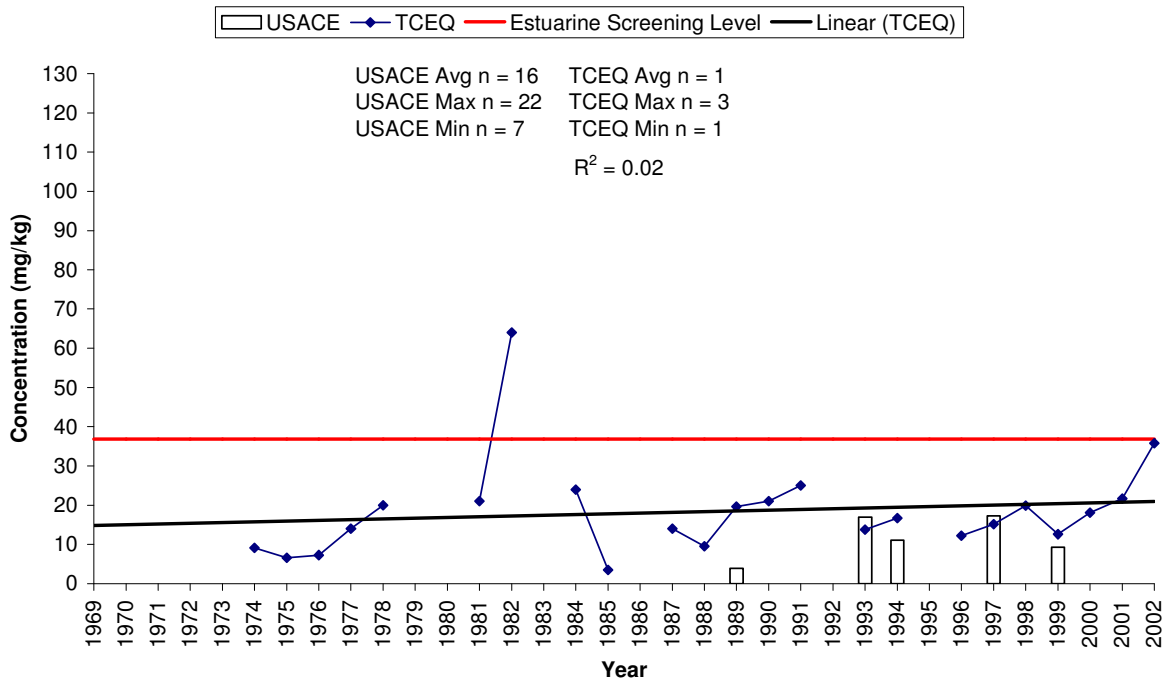


Figure 4.2.1.6. Annual Average Total Chromium in Bottom Deposits in the Lower Houston Ship Channel



### ***Copper***

All water is corrosive toward copper to some degree largely depending on the pH of the water. Moreover, many of the additional factors that affect the corrosiveness of water towards lead (See page 69) can also be expected to affect the corrosion of copper. Once copper is released into water, it can be carried in surface waters either as free copper or bound to particles suspended in the water. Copper primarily binds to organic matter in estuarine sediment, entering the food chain through uptake by bottom feeding organisms.

In 2002, the Status and Trends Project reported no trends in annual average copper concentrations in most of the tributaries and sub-bays of the Galveston Bay Estuary. Of the seven new study areas, the Intracoastal Waterway East and the Galveston Channel lacked sufficient data (less than ten years) to discern a trend. The rest of the areas exhibited no trends.

Table 4.2.1.4. Summary of Annual Trends of Copper in Sediment.

<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	No Trend	0.04
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	No Trend	0.00
Upper Houston Ship Channel	No Trend	0.00
Intracoastal Waterway East	Insufficient Data	--
Trinity River	No Trend	0.07
West Bay	No Trend	0.11

Of interest are the trend graphs for the Upper and Lower Houston Ship Channel (Figures 4.2.1.7 and 4.2.1.8). As with other metals, annual averages based on the data supplied by the USACE are very close to or less than the annual averages derived from the TCEQ data.

The TCEQ Copper in Sediment Tidal Stream Screening Level of 37.2 mg/kg was applied to the Upper Houston Ship Channel (Figure 4.2.1.7). Annual averages in the Upper Houston Ship Channel approached or exceeded the screening level in eight of the last 29 years with the most recent in 2002. In 2002, five of the nine copper in sediment samples exceeded the screening level. Those samples were collected from Patrick and Vince Bayous and the Turning Basin.

Trends from the open bay portions of the Lower Houston Ship Channel were compared to the TCEQ Estuarine Screening Level of 19.9 mg/kg (Figure 4.2.1.8). For the most part, annual average concentrations remained below the screening level.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.1.7. Annual Average Total Copper in Bottom Deposits in the Upper Houston Ship Channel

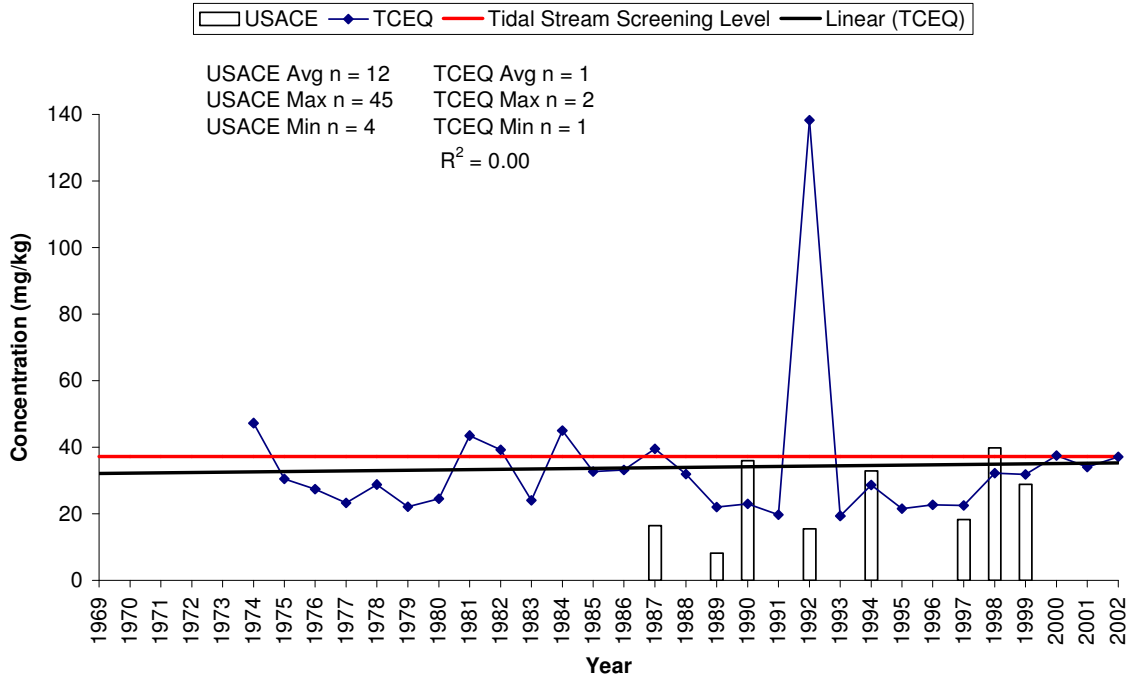
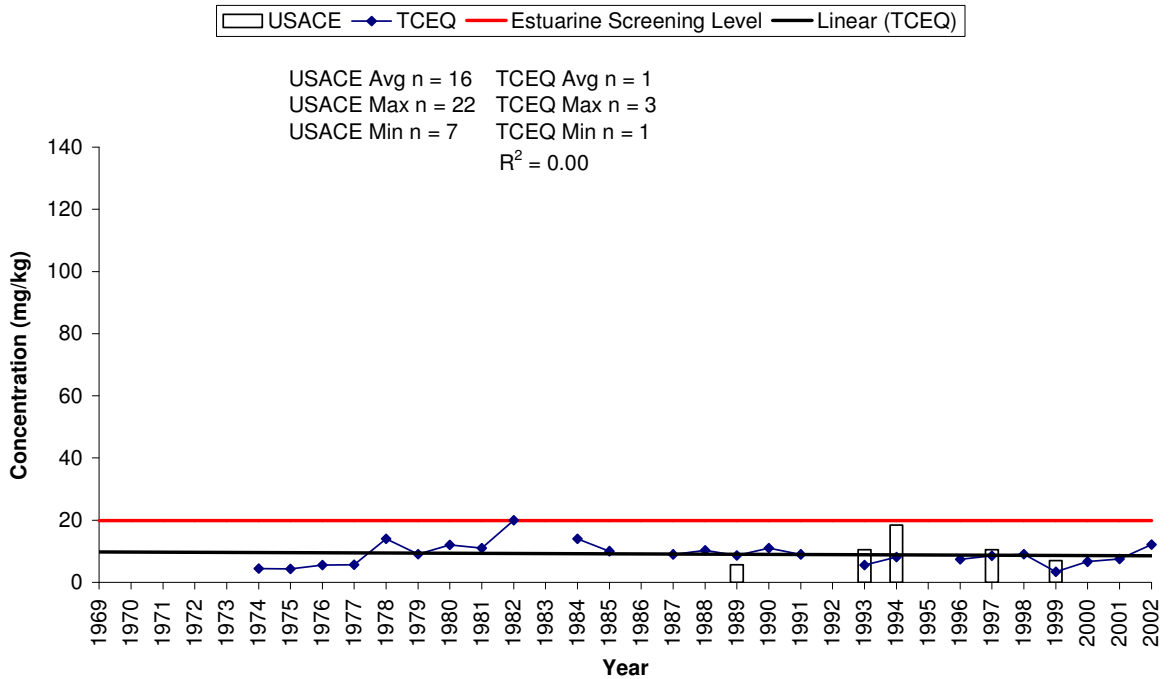


Figure 4.2.1.8. Annual Average Total Copper in Bottom Deposits in the Lower Houston Ship Channel



### **Mercury**

In aquatic systems, particle-bound mercury is converted to insoluble mercury sulfide and precipitated or bioconverted into more volatile or soluble forms that re-enter the atmosphere or bioaccumulate in aquatic and terrestrial food chains. Volatile forms of mercury disperse to the atmosphere, whereas solid forms partition to particulates in soil or in the water column and are transported downward in the water column to the sediments.

A volatile form of mercury is methylmercury, which is soluble and quickly enters the aquatic food chain. Methylmercury in surface water is rapidly accumulated by aquatic organisms. Concentrations in carnivorous fish at the top of both freshwater and marine food chains are biomagnified on the order of 10,000-100,000 times the concentrations found in ambient waters. Fish appear to accumulate methylmercury from food sources and the water column.

In 2002, the Status and Trends Project reported no trends in annual average total mercury concentrations in most of the tributaries and sub-bays of the Galveston Bay Estuary. Of the seven new study areas, the Intracoastal Waterway East, and the Galveston Channel lacked sufficient data (less than ten years) to discern a trend. The Trinity River exhibited an increasing trend. The rest of the areas exhibited no trends.

Table 4.2.1.5. Summary of Annual Trends of Mercury in Sediment.

<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	No Trend	0.06
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	No Trend	0.05
Upper Houston Ship Channel	No Trend	0.04
Intracoastal Waterway East	Insufficient Data	--
Trinity River	Increasing	0.39 (p = 0.072)
West Bay	No Trend	0.14

Of interest are the trend graphs for the Upper Houston Ship Channel and West Bay (Figures 4.2.1.9 and 4.2.1.10). The TCEQ Mercury in Sediment Tidal Stream Screening Level of 0.31 mg/kg was applied to the Upper Houston Ship Channel (Figure 4.2.1.9). Annual averages in the Upper Houston Ship Channel exceeded the screening level in ten of the last 29 years with the most recent in 2002. In 2002, one of the nine mercury in sediment samples exceeded the screening level. That sample was collected in Patrick Bayou.

Trends from West Bay were compared to the TCEQ Estuarine Screening Level of 0.23 mg/kg (Figure 4.2.1.10). Annual average concentrations in West Bay remained below the screening level.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.1.9. Annual Average Dissolved Mercury in Bottom Deposits in the Upper Houston Ship Channel

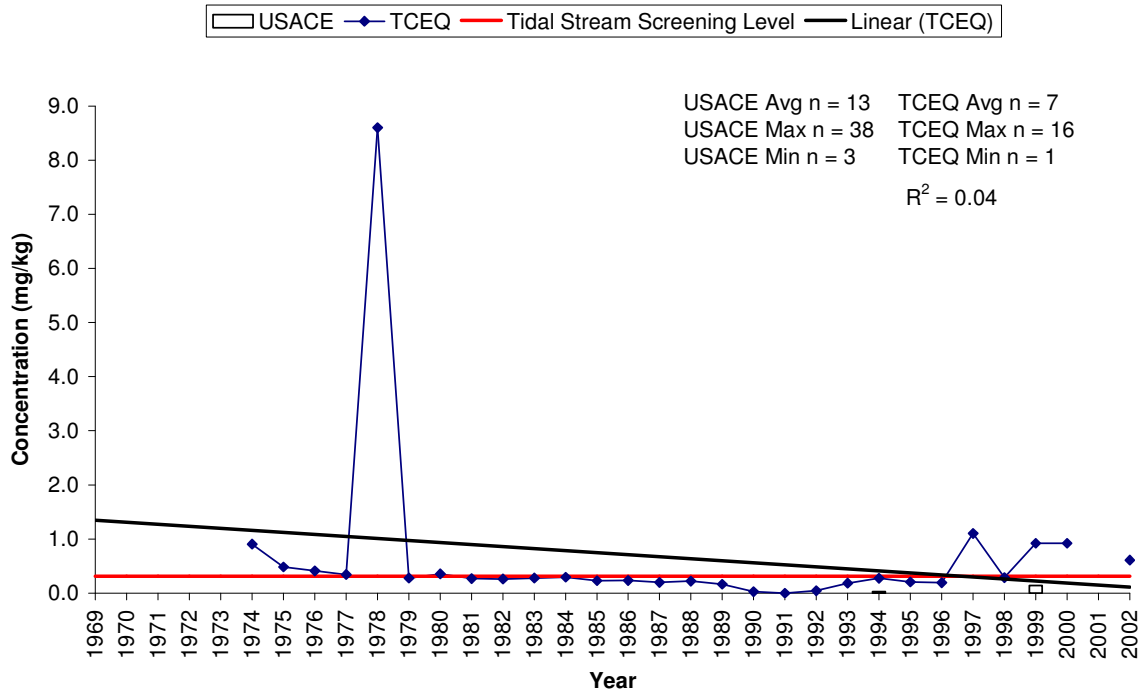
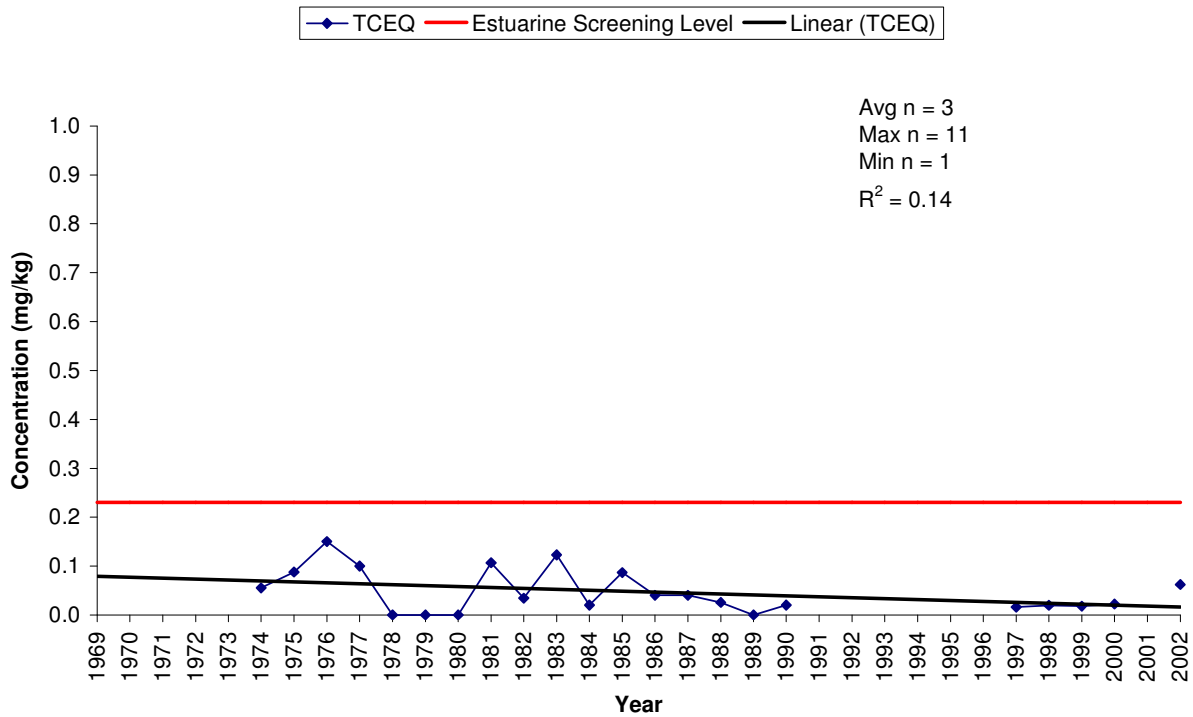


Figure 4.2.1.10. Annual Average Dissolved Mercury in Bottom Deposits in West Bay



### ***Nickel***

Much of the nickel released into waterways as runoff is bound to transported particulate matter which settles out in areas such as mouths of rivers. Nickel can be released from the sediment in the presence of sulfide ions (through the oxidation of sulfur compounds to sulfuric acid). When released, nickel is one of the most mobile of the heavy metals and bioaccumulates in the food chain.

As reported in the 2002 Status and Trends report, annual average concentrations of nickel declined or exhibited no trends for most areas of Galveston Bay. Of the seven new study areas, the Intracoastal Waterway East, the Galveston Channel, and the Christmas Bay/Bastrop Bayou Complex lacked sufficient data (less than ten years) to discern a trend. West Bay had a decreasing trend. The rest of the areas exhibited no trends.

Table 4.2.1.6. Summary of Annual Trends of Nickel in Sediment.

<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	Decreasing	0.82 (p < 0.001)
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	No Trend	0.03
Upper Houston Ship Channel	No Trend	0.13
Intracoastal Waterway East	Insufficient Data	--
Trinity River	No Trend	0.03
West Bay	Decreasing	0.33 (p = 0.007)

Of interest are the trend graphs for the Upper and Lower Houston Ship Channel (Figures 4.2.1.11 and 4.2.1.12). With the exception of the annual average for 1997, annual averages based on the data supplied by the USACE are very similar to or less than the annual averages derived from the TCEQ data. The TCEQ Nickel in Sediment Tidal Stream Screening Level of 23.8 mg/kg was applied to the Upper Houston Ship Channel (Figure 4.2.1.11). Annual averages in the Upper Houston Ship Channel exceeded the screening level during three years with the most recent being 1992.

Trends from West Bay were compared to the TCEQ Estuarine Screening Level of 21.4 mg/kg (Figure 4.2.1.12). Annual average concentrations in West Bay remained at or below the screening level.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.1.11. Annual Average Total Nickel in Bottom Deposits in the Upper Houston Ship Channel

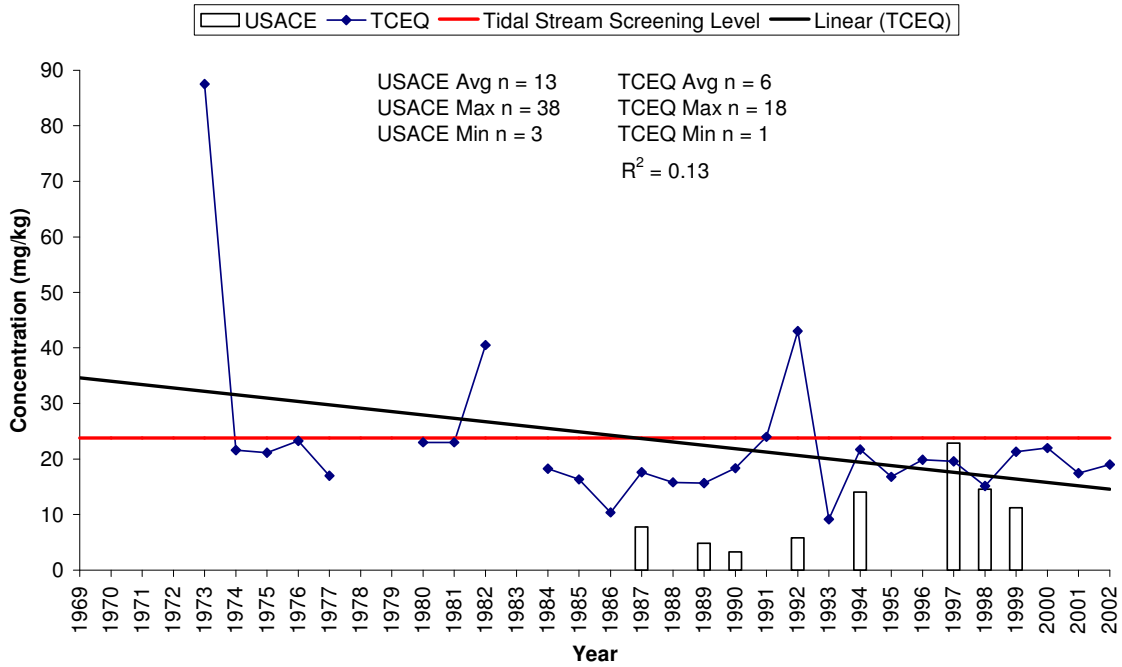
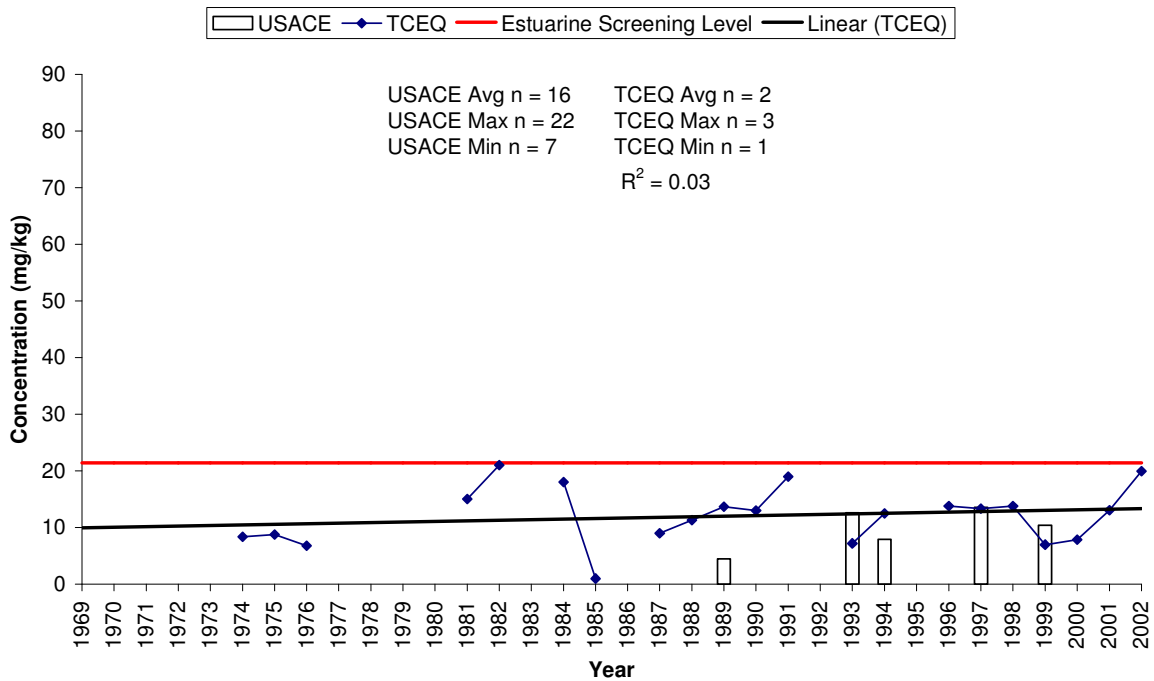


Figure 4.2.1.12. Annual Average Total Nickel in Bottom Deposits in the Lower Houston Ship Channel



### **Lead**

Lead is extremely persistent in both water and soil. Largely associated with suspended solids and sediments in aquatic systems, lead occurs in relatively immobile forms. Although no significant biomagnification has been detected (except in some shellfish), plants and animals are known to bioconcentrate lead. High bioconcentration factors were determined in studies using oysters, algae, and rainbow trout. In general, the highest lead concentrations are found in aquatic and terrestrial organisms that live in areas affected by high automobile and truck traffic, areas of heavy hunting (in the past waterfowl hunters used lead shot, which is now banned), urbanization, and industrialization. Lead concentrations are usually higher in benthic organisms and algae, and lower in upper trophic level predators.

As reported in the 2002 Status and Trends report, annual average trends in concentrations of lead were difficult to discern for most areas of Galveston Bay. Of the seven new study areas, the Intracoastal Waterway East and the Galveston Channel lacked sufficient data (less than ten years) to discern a trend. The Christmas Bay/Bastrop Bayou Complex and Upper Houston Ship Channel had decreasing trends. The rest of the areas exhibited no trends.

Table 4.2.1.7. Summary of Annual Trends of Lead in Sediment.

<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	Decreasing	0.48 (p = 0.012)
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	No Trend	0.01
Upper Houston Ship Channel	Decreasing	0.28 (p = 0.003)
Intracoastal Waterway East	Insufficient Data	--
Trinity River	No Trend	0.00
West Bay	No Trend	0.21

Of interest are the trend graphs for the Upper and Lower Houston Ship Channel (Figures 4.2.1.13 and 4.2.1.14). As with other metals, annual averages based on the data supplied by the USACE are very similar to or less than the annual averages derived from the TCEQ data. The TCEQ Lead in Sediment Tidal Stream Screening Level of 72.3 mg/kg was applied to the Upper Houston Ship Channel (Figure 4.2.1.13). Annual averages in the Upper Houston Ship Channel exceeded the screening level during 12 of the last 29 years with the most recent being 1998. Five lead in sediment samples were collected that year in the Upper Houston Ship Channel, of which one sample from Vince Bayou exceeded the screening level.

Trends from the open bay portions of the Lower Houston Ship Channel were compared to the TCEQ Estuarine Screening Level of 21.9 mg/kg (Figure 4.2.1.14). Annual average concentrations in the Lower Houston Ship Channel exceeded the screening level in four of the last 29 years.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.1.13. Annual Average Total Lead in Bottom Deposits in the Upper Houston Ship Channel

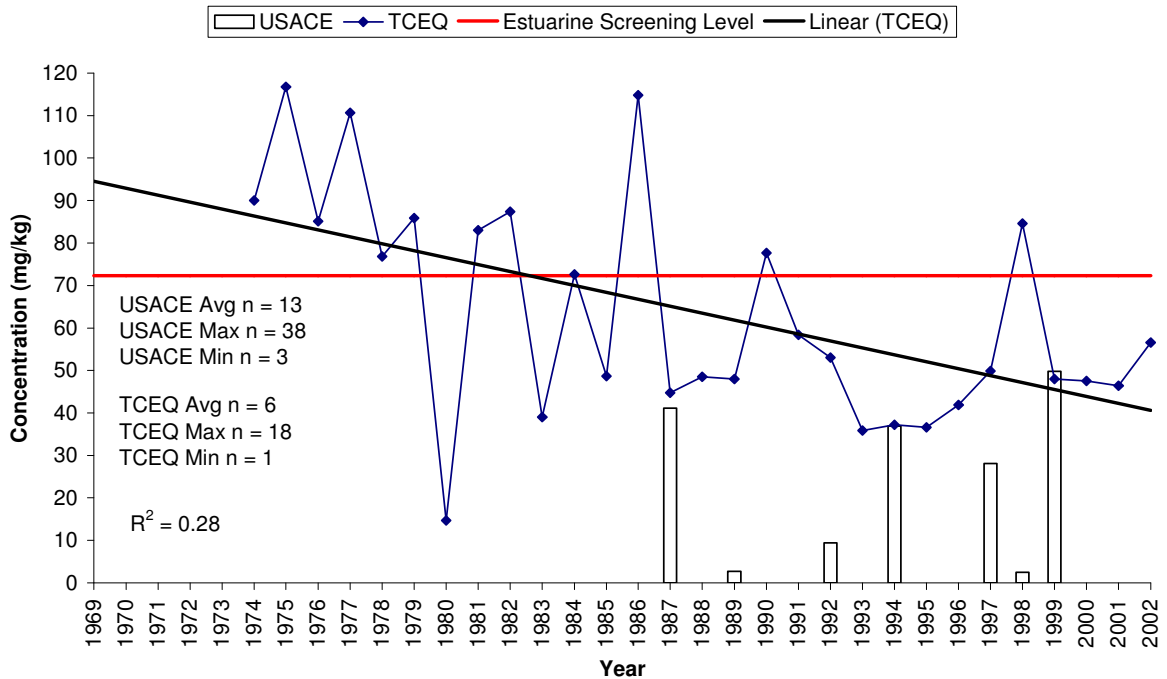
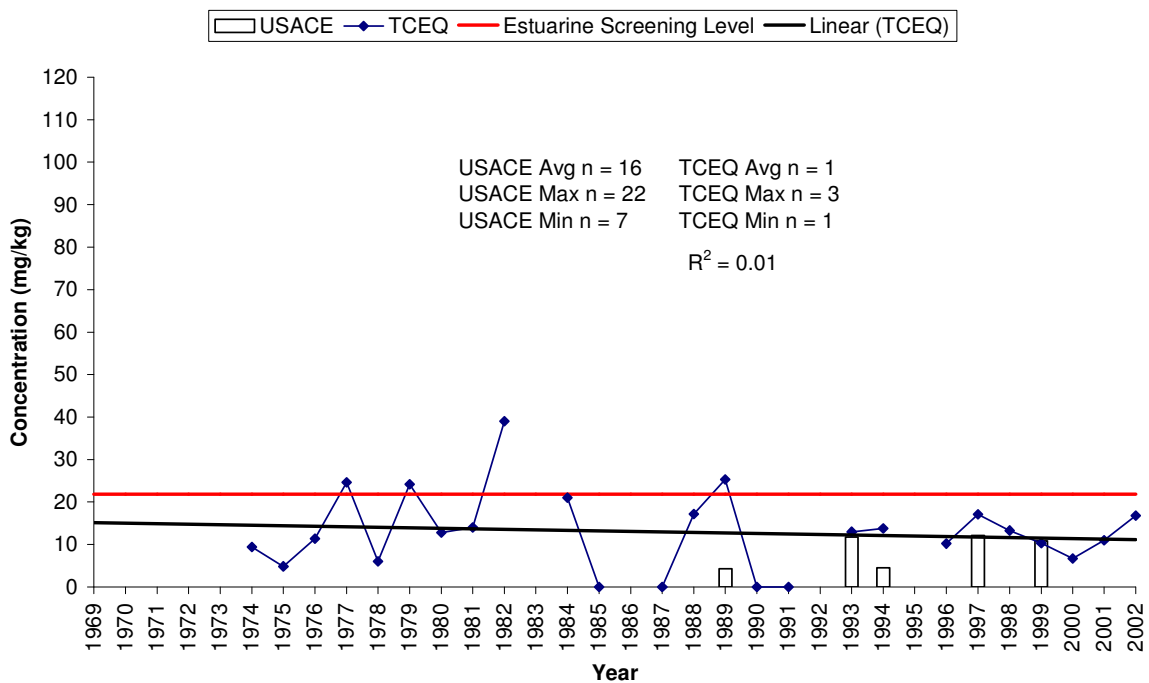


Figure 4.2.1.14. Annual Average Total Lead in Bottom Deposits in the Lower Houston Ship Channel



## Zinc

In the aquatic environment, zinc is partitioned into sediments or suspended solids through sorption onto hydrous iron and manganese oxides, clay minerals, and organic material. Zinc tends to concentrate more readily in bottom sediments than in the surrounding soils. Certain biological activity can affect the mobility of zinc while in anaerobic environments. As with other metals, zinc can be mobilized in the presence of sulfide ions (through the oxidation of sulfur compounds to sulfuric acid). Precipitation of zinc sulfide can also limit its mobility causing zinc to bioconcentrate in benthic organisms.

As reported in the 2002 Status and Trends report, annual average concentrations of zinc exhibited no trends for most areas of Galveston Bay. Trinity Bay was the only area to have an increasing trend ( $R^2 = 0.56$ ). Of the seven new study areas, the Intracoastal Waterway East and the Galveston Channel lacked sufficient data (less than ten years) to discern a trend. The Christmas Bay/Bastrop Bayou Complex was the only area to show a decreasing trend, although that is based on only 12 years of data. The rest of the areas exhibited no trends.

Table 4.2.1.8. Summary of Annual Trends of Zinc in Sediment.

Study Area	Trend Direction	R <sup>2</sup> Value
Christmas Bay/Bastrop Bayou	Decreasing	0.33 (p = 0.05)
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	No Trend	0.06
Upper Houston Ship Channel	No Trend	0.20
Intracoastal Waterway East	Insufficient Data	--
Trinity River	No Trend	0.08
West Bay	No Trend	0.10

Of interest are the trend graphs for the Upper and Lower Houston Ship Channel (Figures 4.2.1.15 and 4.2.1.16). As with other metals, annual averages based on the data supplied by the USACE are very similar to or less than the annual averages derived from the TCEQ data with the exception of the Upper Houston Ship Channel in 1994. The TCEQ Zinc in Sediment Tidal Stream Screening Level of 200 mg/kg was applied to the Upper Houston Ship Channel (Figure 4.2.1.15). Annual averages in the Upper Houston Ship Channel exceeded the screening level during ten of the last 29 years, the most recent being in the year 2000. During that year, twelve zinc in sediment samples were collected in the Upper Houston Ship Channel, six of which (from Patrick Bayou, Vince Bayou, and the Turning Basin) exceeded the screening level.

Trends from the open bay portions of the Lower Houston Ship Channel were compared to the TCEQ Estuarine Screening Level of 107 mg/kg (Figure 4.2.1.16). Annual average concentrations in the Lower Houston Ship Channel did not exceed the screening over the last 29 years.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.1.15. Annual Average Total Zinc in Bottom Deposits in the Upper Houston Ship Channel

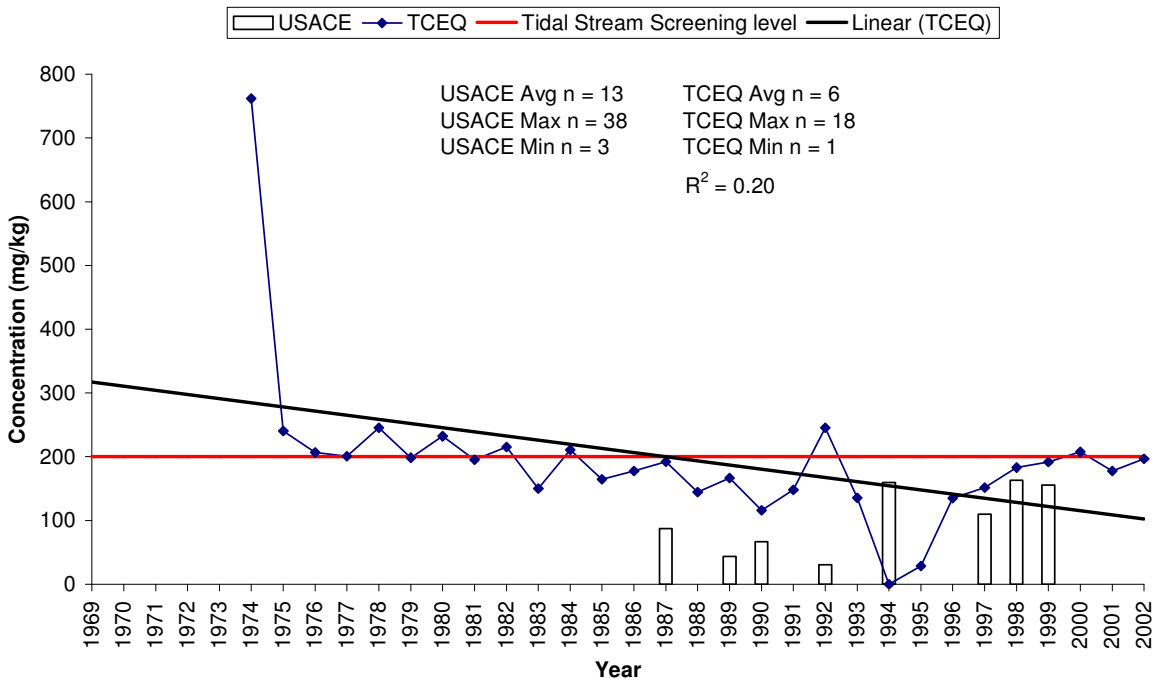
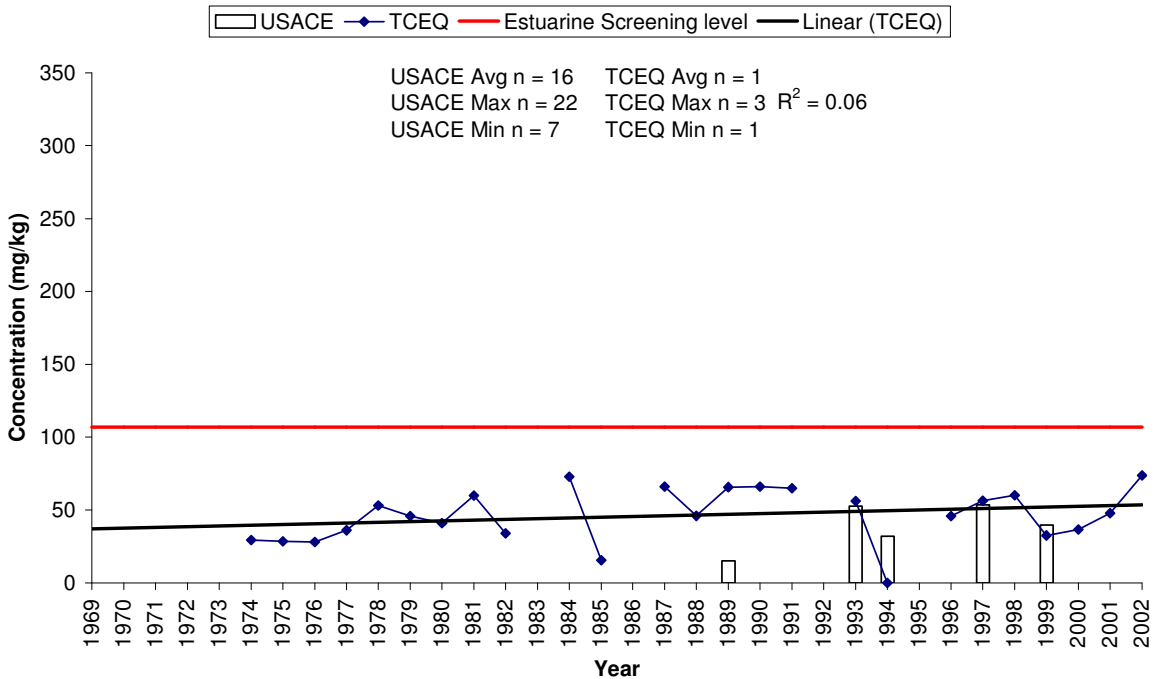


Figure 4.2.1.16. Annual Average Total Zinc in Bottom Deposits in the Lower Houston Ship Channel



#### 4.2.2. Organic Compounds

Data on the concentration of organic compounds and pesticides in bottom deposits (sediments) of Galveston Bay were collected by the TCEQ from 1974-2002. The Status and Trends Project analyzed these data for the new study areas. Data sets for some tributaries (the Galveston Channel and the Intracoastal Waterway East) contained less than 10 years of data and made trend analysis impractical. The organic compounds studied include aldrin, chlordane, DDD, DDE, DDT, diazinon, dieldrin, endrin, PCBs and benzo-a-pyrene.

For the purposes of the Status and Trends analysis, concentrations identified by the TCEQ as being below detection limits were converted to zero, the prevalence of values less than detection limits is evident on many of the graphs included in this section. The organics in sediment database contains gaps where data for a given compound may not have been collected in a sub-bay or tributary for several years in a row. Additionally, some annual averages are calculated based on only a few samples collected per area per year. To aid the reader, each trend graph is annotated with the average, minimum, and maximum sample size for each yearly average. An  $R^2$  value is also included in each graph to aid the reader in determining significance of the trend. The Status and Trends Project does not consider a trend to be significant if  $R^2 < 0.25$ . This approach was taken to ensure consistency for comparison across parameters. Statistical significance of a trend is achieved at a lower  $R^2$  value if sample size is high, but when sample size is low, higher  $R^2$  values may not be statistically significant. To avoid confusing the reader, area-parameter combinations with low sample sizes were eliminated and a consistent  $R^2$  value was chosen.

##### ***Aldrin***

Aldrin is an agricultural insecticide that was used in the 1950s to 1970s mostly on cotton and corn crops. Its use was completely banned in the United States in 1987 (ATSDR, 2003). However, because of the persistent nature of the compound it is still present in the environment. Volatilization of aldrin from water surfaces is expected, however, its volatility may be weakened by adsorption to suspended solids and sediments. Aldrin bioconcentrates in aquatic organisms and may be converted to dieldrin.

Of the seven new study areas, the Christmas Bay/Bastrop Bayou Complex, Galveston Channel, Intracoastal Waterway East, and Trinity River lacked sufficient data (less than ten years) to discern a trend. The rest of the areas exhibited no trends.

Table 4.2.2.1. Summary of Annual Trends of Aldrin in Sediment. BDL=All data below detection limits.

Study Area	Trend Direction	R <sup>2</sup> Value
Christmas Bay/Bastrop Bayou	Insufficient Data	--
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	BDL	--
Upper Houston Ship Channel	No Trend	0.11
Intracoastal Waterway East	Insufficient Data	--
Trinity River	Insufficient Data	--
West Bay	No Trend	0.22

Of interest are the trend graphs for the Upper Houston Ship Channel and West Bay (Figures 4.2.2.1 and 4.2.2.2). Annual averages based on the data supplied by the USACE are similar to the annual averages derived from the TCEQ data.

The TCEQ Aldrin in Sediment Tidal Stream Screening Level of 21.0 ug/kg was applied to the Upper Houston Ship Channel (Figure 4.2.2.1). Annual averages in the Upper Houston Ship Channel exceeded the screening level in three of the last 29 years (1974, 1975, and 1976). The extremely high annual average in 1974 is based on four samples, with one being below detection limits. The three remaining samples collected in 1974 measured 7290 ug/kg (two samples at the San Jacinto Park) and 3100 ug/kg (one sample taken near Morgan's Point). Most of the samples collected in 1975 and 1976 also measured below detection limits, but two samples collected at the Turning Basin and the confluence with Sims Bayou measured 166 ug/kg and 157.8 ug/kg respectively.

Trends from West Bay were compared to the TCEQ Estuarine Screening Level of 13.0 ug/kg (Figure 4.2.2.2). For the most part, concentrations were below the detection limit.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.2.1. Annual Average Aldrin in Bottom Deposits in the Upper Houston Ship Channel

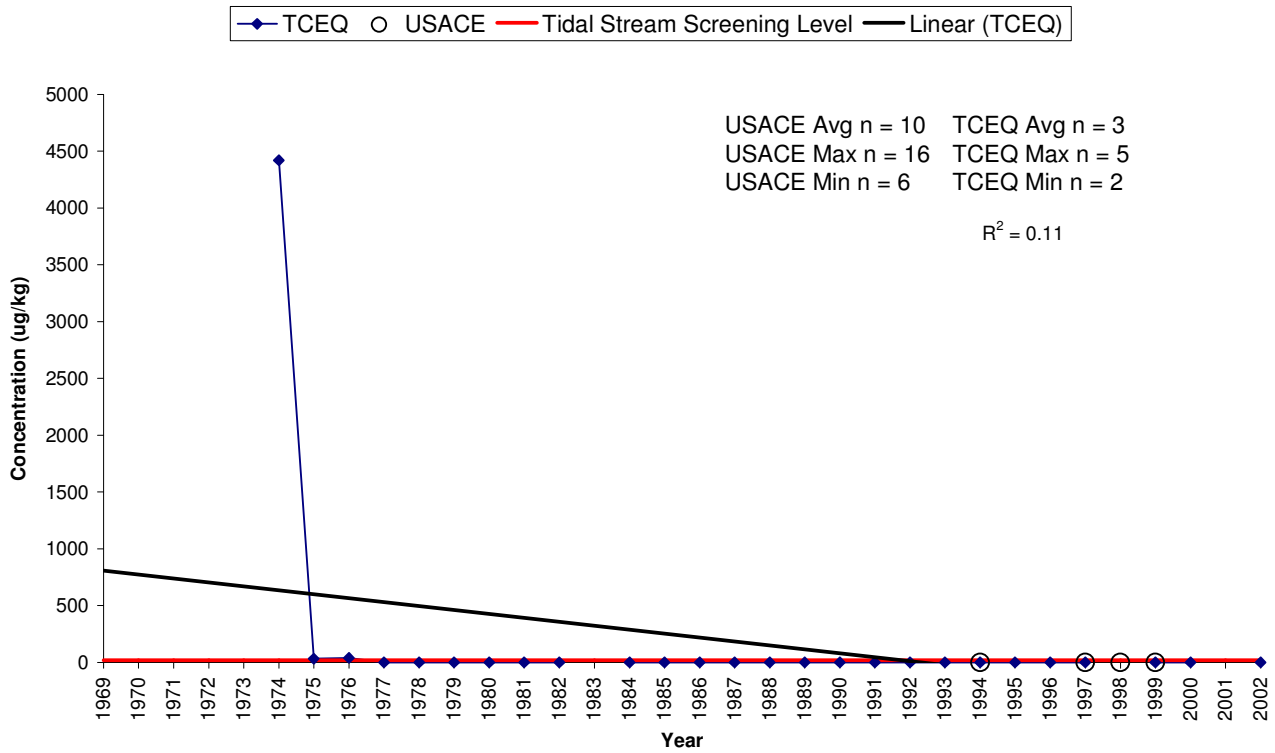
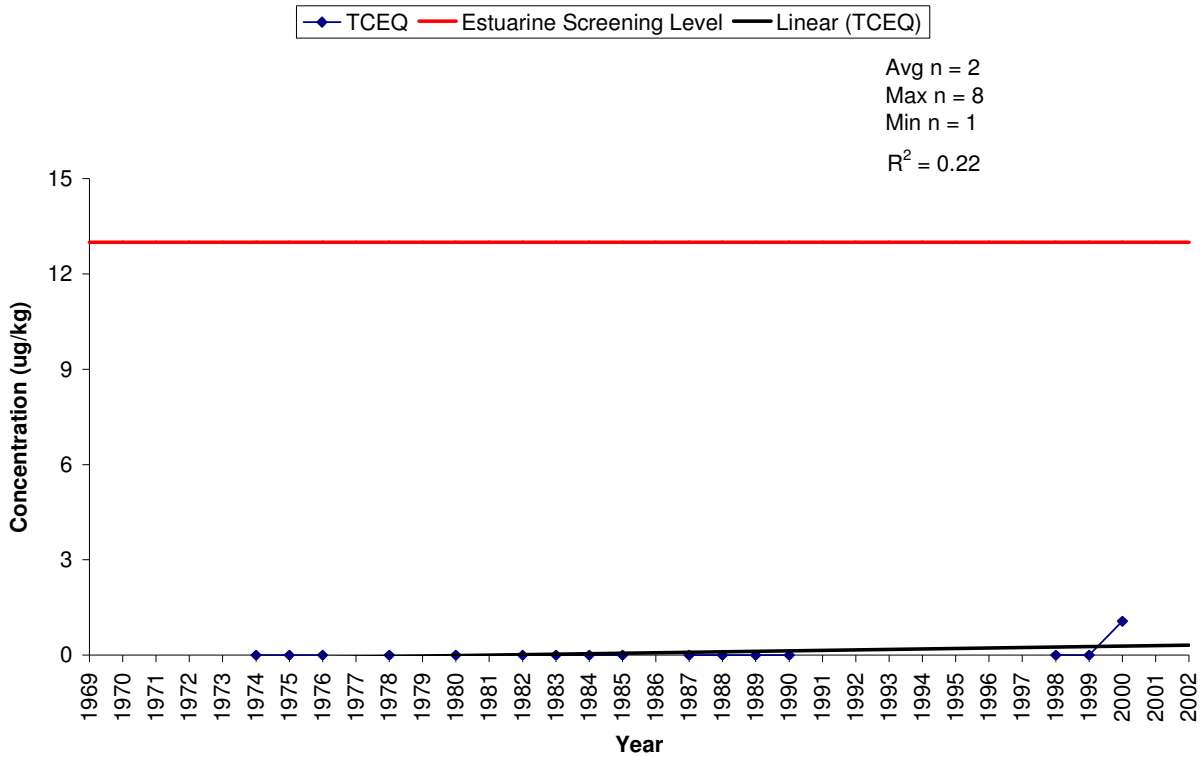


Figure 4.2.2.2. Annual Average Aldrin in Bottom Deposits in West Bay



### ***Chlordane***

Chlordane is a synthetic chemical that was used as a pesticide on crops including corn and citrus, on home lawns and gardens, and as a termite control. The use of chlordane was completely banned in the United States in 1987 (ATSDR, 2003). However, chlordane is still detected in surface water, groundwater, suspended solids, sediments, bottom detritus, drinking water, sewage sludge, urban runoff and rainwater. Chlordane does not dissolve easily in water and can remain in top layers of the soil for over 20 years. Chlordane bioconcentrates in roots of vascular plants growing in contaminated sediments, is translocated into the shoots, and may be ingested by aquatic animals.

Of the seven new study areas, the Christmas Bay/Bastrop Bayou Complex, Galveston Channel, Intracoastal Waterway East, and Trinity River lacked sufficient data (less than ten years) to discern a trend. Two areas exhibited no trends while West Bay had values below detection limits for all years.

Table 4.2.2.2. Summary of Annual Trends of Chlordane in Sediment.

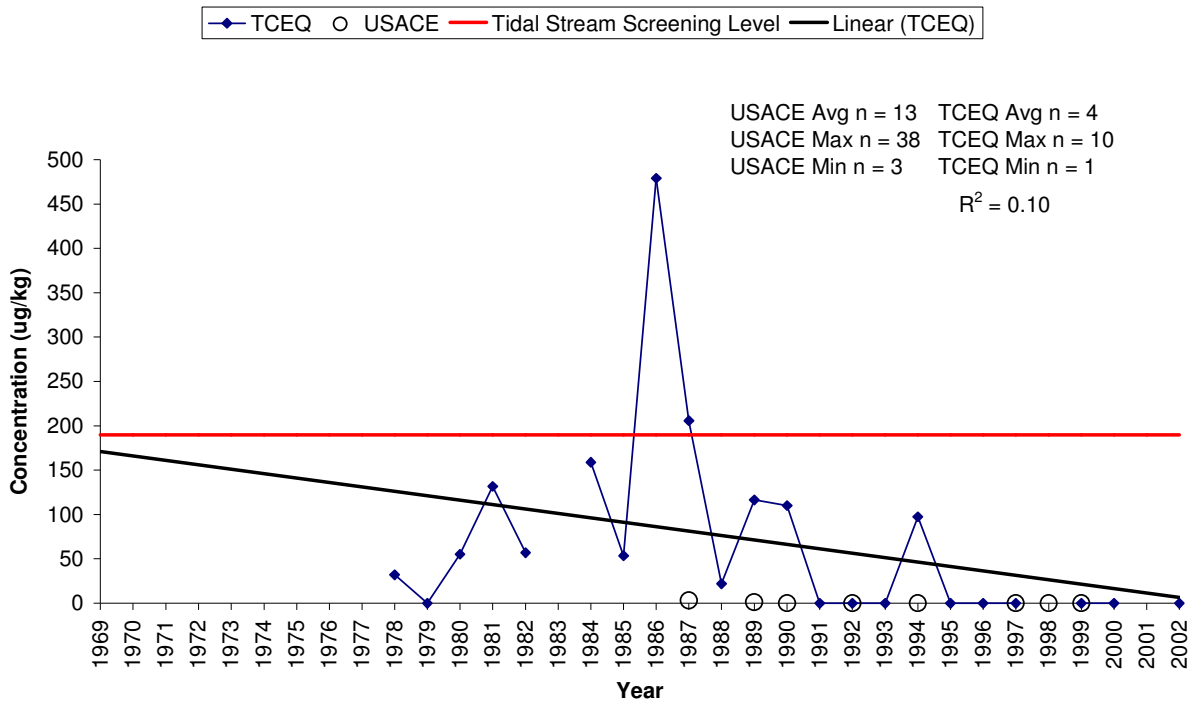
<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	Insufficient Data	--
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	No Trend	0.01
Upper Houston Ship Channel	No Trend	0.10
Intracoastal Waterway East	Insufficient Data	--
Trinity River	Insufficient Data	--
West Bay	Increasing	0.27 (p = 0.084)

Of interest is the trend graph for the Upper Houston Ship Channel (Figure 4.2.2.3). Annual averages based on the data supplied by the USACE are similar to the annual averages derived from the TCEQ data.

The TCEQ Chlordane in Sediment Tidal Stream Screening Level of 190.0 ug/kg was applied to the Upper Houston Ship Channel (Figure 4.2.2.3). One year (1986) out of the last 29 years exhibited annual averages exceed the screening level. Of the four samples collected in the Upper Houston Ship Channel in 1986, three samples exceeded the screening level. The elevated concentrations originated from the Turning Basin, the confluence with Sims Bayou and the confluence with Greens Bayou.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.2.3. Annual Average Chlordane in Bottom Deposits in the Upper Houston Ship Channel



**Diazinon**

Diazinon is an organophosphorus insecticide used commonly by homeowners on lawns, gardens and inside the home (ATSDR, 2003). Diazinon is known to be highly toxic to fish as well as humans. The mechanisms that fish and invertebrates use to metabolize diazinon are poorly understood and seem to vary widely from species to species. Diazinon is easily introduced to fresh and salt water food chains because it seldom migrates below the top half inch of soil and is readily transported by stormwater runoff. It is usually broken down into a variety of other chemicals once in the environment. The breakdown products are readily available for uptake.

Of the seven new study areas, the Christmas Bay/Bastrop Bayou Complex, Galveston Channel, Intracoastal Waterway East, and Trinity River lacked sufficient data (less than ten years) to discern a trend. Concentrations for the Upper Houston Ship Channel remained below detection limits. West Bay exhibited no trend. Of interest is the trend graph for the Lower Houston Ship Channel (Figure 4.2.2.4).

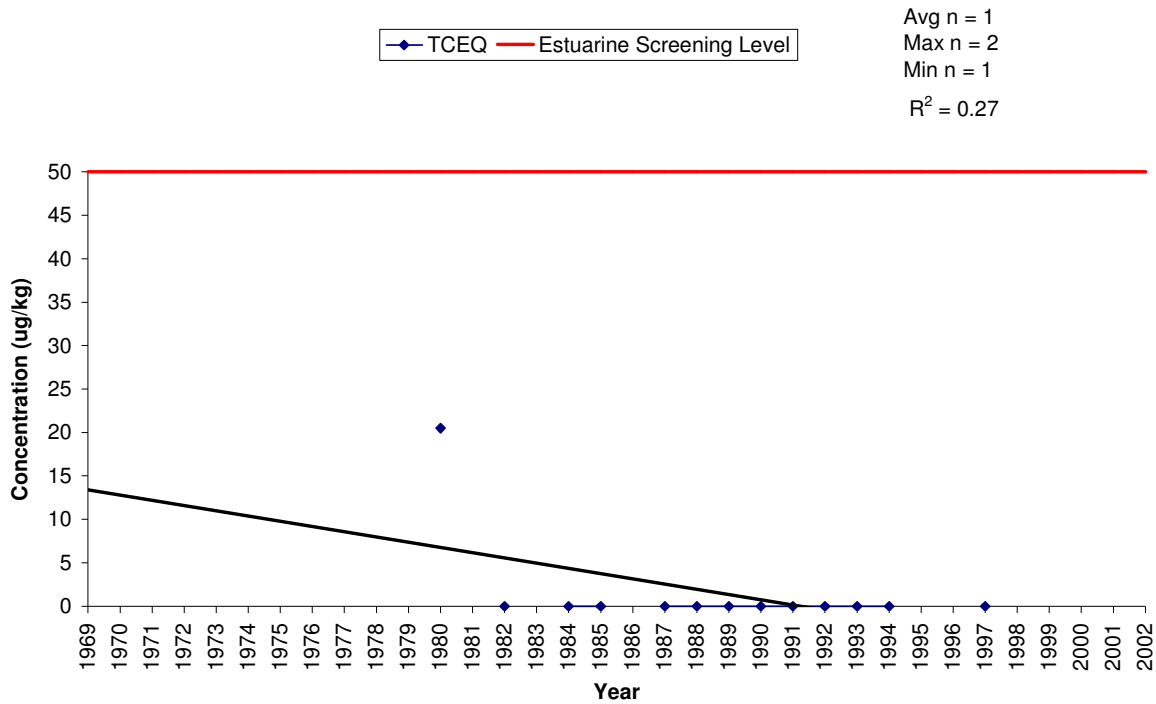
Table 4.2.2.4. Summary of Annual Trends of Diazinon in Sediment. BDL=All data below detection limits.

Study Area	Trend Direction	R <sup>2</sup> Value
Christmas Bay/Bastrop Bayou	Insufficient Data	--
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	Decreasing	0.27 (p = 0.066)
Upper Houston Ship Channel	BDL	--
Intracoastal Waterway East	Insufficient Data	--
Trinity River	Insufficient Data	--
West Bay	Increasing	0.36 (p = 0.050)

The TCEQ Diazinon in Sediment Estuarine Screening Level of 50.0 ug/kg was applied to the Lower Houston Ship Channel trend graph. Annual averages in the Lower Houston Ship Channel generally remained below detection limits with the exception of 1980 which included a sample with a concentration of 41.0 ug/kg collected from a station between Smith Point and Eagle Point.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.2.4. Annual Average Diazinon in Bottom Deposits in the Lower Houston Ship Channel



### ***Dieldrin***

Dieldrin is both a breakdown product of aldrin (see page 73) and a synthetic chemical used as a pesticide. The use of dieldrin was completely banned in the United States in 1987 (ATSDR, 2003). Dieldrin does not readily dissolve in water, but binds to soil and sediment. Fish and other animals that consume contaminated materials store a large amount of the dieldrin in their adipose tissue. Food chain bioaccumulation is an important fate for dieldrin, as it biomagnifies in aquatic and terrestrial food chains.

Of the seven new study areas, the Christmas Bay/Bastrop Bayou Complex, Galveston Channel, Intracoastal Waterway East, and Trinity River lacked sufficient data (less than ten years) to discern a trend. Concentrations for the Lower Houston Ship Channel remained below detection limits. Of interest are the trend graphs for the Upper Houston Ship Channel and West Bay (Figures 4.2.2.5 and 4.2.2.6).

Table 4.2.2.4. Summary of Annual Trends of Dieldrin in Sediment. BDL=All data below detection limits.

<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	Insufficient Data	--
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	BDL	--
Upper Houston Ship Channel	Decreasing	0.35 (p = 0.001)
Intracoastal Waterway East	Insufficient Data	--
Trinity River	Insufficient Data	--
West Bay	No Trend	0.22

The TCEQ Dieldrin in Sediment Tidal Stream Screening Level of 15.0 ug/kg was applied to the Upper Houston Ship Channel trend graph. Annual averages based on the data supplied by the USACE are similar to the annual averages derived from the TCEQ data. Annual averages in the Upper Houston Ship Channel remained below the screening level. Seven dieldrin samples out of 102 collected from 1974-2002 exceeded the screening level. Six of the seven samples were collected within the Turning Basin. One sample exceeding the screening level was collected at the confluence with Sims Bayou.

For the most part, annual average concentrations in West Bay were below the detection limit.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.2.5. Annual Average Dieldrin in Bottom Deposits in the Upper Houston Ship Channel

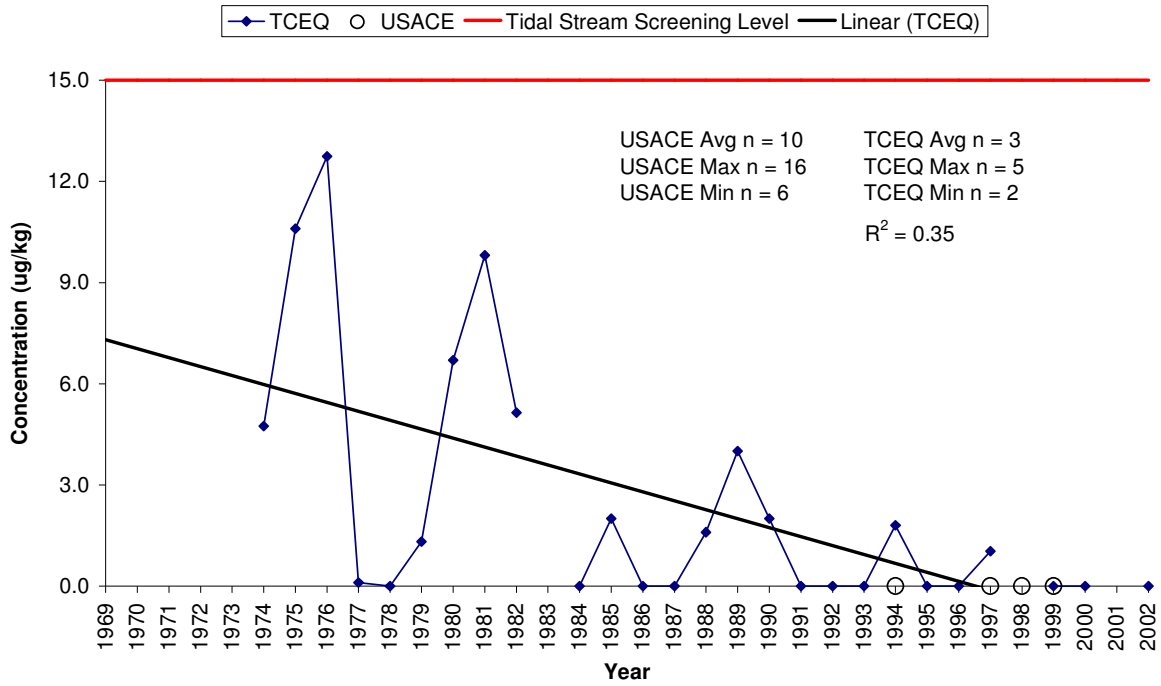
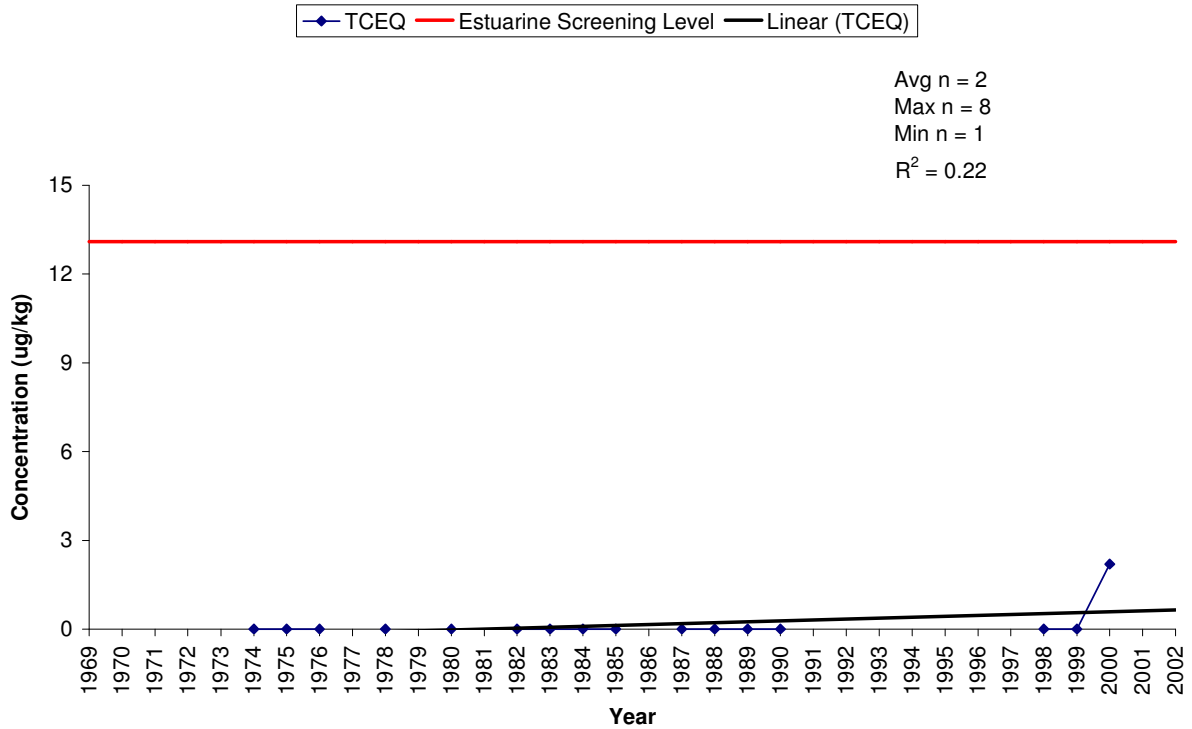


Figure 4.2.2.6. Annual Average Dieldrin in Bottom Deposits in West Bay



### ***Endrin***

Endrin was a pesticide manufactured for use on rodents, insects, and birds. Endrin has not been sold for general use in the U.S. since 1986 (ATSDR, 2003). The persistence of endrin in the environment depends upon local conditions. It is estimated to persist in soil for over ten years, and binds to bottom sediments in bodies of water. When endrin is released into an aquatic system it adsorbs to surface sediment and bioconcentrates considerably in organisms.

Of the seven new study areas, the Christmas Bay/Bastrop Bayou Complex, Galveston Channel, Intracoastal Waterway East, and Trinity River lacked sufficient data (less than ten years) to discern a trend. Concentrations for the Lower and Upper Houston Ship Channel remained below detection limits. Of interest are the trend graphs for West Bay (Figure 4.2.2.7).

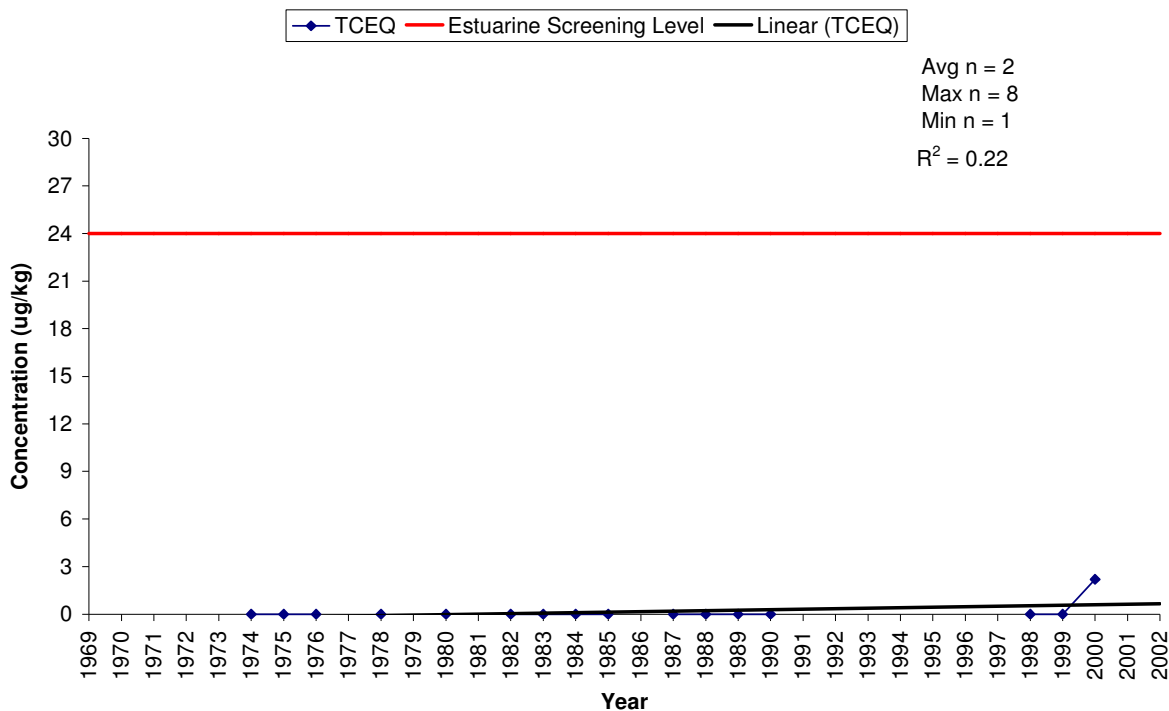
Table 4.2.2.5. Summary of Annual Trends of Endrin in Sediment. BDL=All data below detection limits.

<b>Study Area</b>	<b>Trend Direction</b>	<b>R<sup>2</sup> Value</b>
Christmas Bay/Bastrop Bayou	Insufficient Data	--
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	BDL	--
Upper Houston Ship Channel	BDL	--
Intracoastal Waterway East	Insufficient Data	--
Trinity River	Insufficient Data	--
West Bay	No Trend	0.22

The TCEQ Endrin in Sediment Estuarine Screening Level of 24.0 ug/kg was applied to the West Bay trend graph. For the most part, annual average concentrations in West Bay were below the detection limit.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.2.7. Annual Average Endrin in Bottom Deposits in West Bay



### ***DDT, DDD, DDE***

DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane) is a synthetic chemical that was widely used to control agricultural and disease-causing insects. Two similar chemicals are DDD (1,1-dichloro-2,2-bis(p-chlorophenyl) ethane) and DDE (1,1-dichloro-2,2-bis(p-chlorophenyl) ethylene). DDD was also used to kill pests, while DDE had no commercial use. All three compounds were banned from use in the United States, however, DDT is still used in other parts of the world (ATSDR, 2003).

DDT, DDD, and DDE are lipid-soluble, highly persistent compounds that bioaccumulate in aquatic organisms. This leads to the progressive biomagnification of DDT in organisms at the top of the food chain that feed on the organisms at lower trophic levels that contain the compound. DDT, DDD and DDE also have a very long residence time in bodies of water. Direct photolysis of DDT and DDD are low in aquatic systems, creating an estimated half-life of more than 150 years.

Of the seven new study areas, the Christmas Bay/Bastrop Bayou Complex, Galveston Channel, Lower Houston Ship Channel, Intracoastal Waterway East, Trinity River, and West Bay lacked sufficient data (less than ten years) to discern a trend. Of interest are the trend graphs for the Upper Houston Ship Channel (Figures 4.2.2.8, 4.2.2.9 and 4.2.2.10).

Table 4.2.2.6. Summary of Annual Trends of DDT, DDD and DDE in Sediment.

Study Area		Trend Direction	R <sup>2</sup> Value
Christmas Bay/Bastrop Bayou	DDT	Insufficient Data	--
	DDD	Insufficient Data	--
	DDE	Insufficient Data	--
Galveston Channel	DDT	Insufficient Data	--
	DDD	Insufficient Data	--
	DDE	Insufficient Data	--
Lower Houston Ship Channel	DDT	Insufficient Data	--
	DDD	Insufficient Data	--
	DDE	Insufficient Data	--
Upper Houston Ship Channel	DDT	No Trend	0.11
	DDD	No Trend	0.08
	DDE	No Trend	0.11
Intracoastal Waterway East	DDT	Insufficient Data	--
	DDD	Insufficient Data	--
	DDE	Insufficient Data	--
Trinity River	DDT	Insufficient Data	--
	DDD	Insufficient Data	--
	DDE	Insufficient Data	--
West Bay	DDT	Insufficient Data	--
	DDD	Insufficient Data	--
	DDE	Insufficient Data	--

The TCEQ Tidal Stream Screening Levels for DDT, DDD, and DDE in sediment (37.0 ug/kg, 65.0 ug/kg, 30.0 ug/kg respectively) were applied to trend graphs for the Upper Houston Ship Channel (Figures 4.2.2.8, 4.2.2.9 and 4.2.2.10). For the most part, annual average concentrations in the Upper Houston Ship Channel were below the screening levels. Exceptions include nine out of 102 samples for DDT that were above the screening level of 37.0 ug/kg. The nine samples were collected in 1974, 1978, 1982, 1986, 1988, and 1997 at San Jacinto Park, Morgan's Point, the Turning Basin, the confluence with Greens Bayou, and the confluence with Sims Bayou. DDT data collected by the USACE are displayed along with the TCEQ data.

Two out of 101 samples for DDD were above the 65.0 ug/kg screening level. The two samples were collected in 1975 and 1986 at the confluence with Greens Bayou. Five out of 101 samples for DDE were above the 30.0 ug/kg screening level. The five samples were collected in 1974 and 1981 at San Jacinto Park, Morgan's Point, the confluence with Greens Bayou, and the Turning Basin. DDD and DDE are not measured by USACE during maintenance dredging operations and are therefore not available for a corresponding graphical display.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.2.8. Annual Average DDT in Bottom Deposits in the Upper Houston Ship Channel

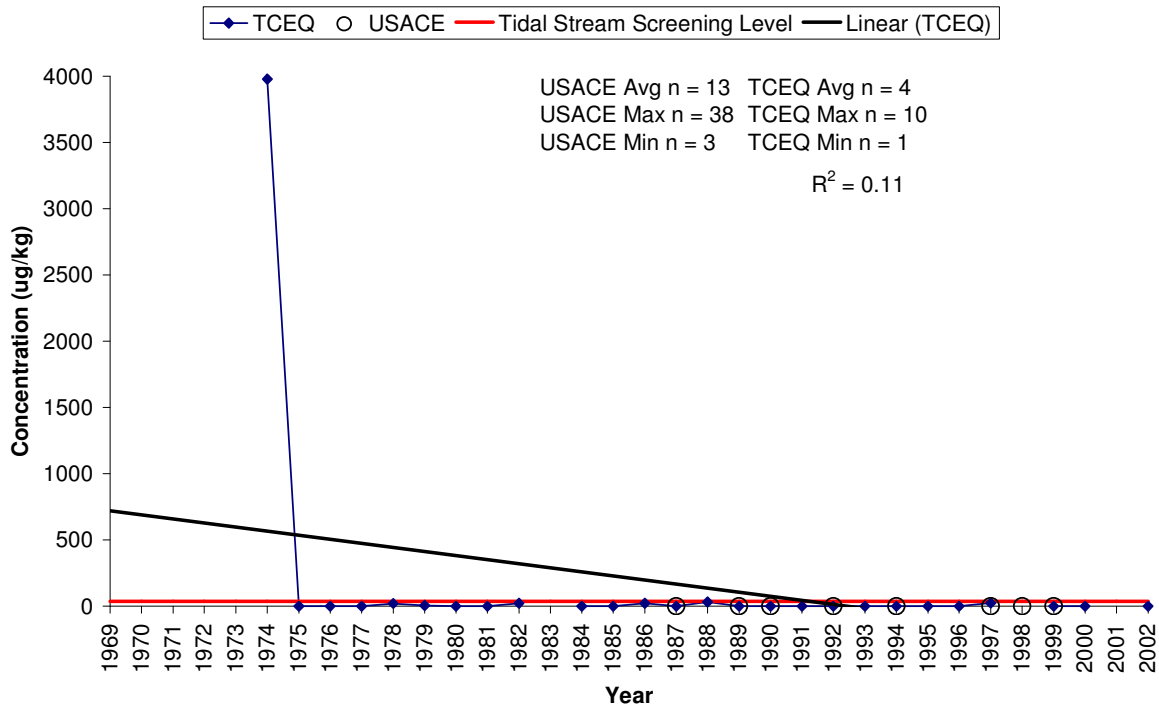


Figure 4.2.2.9. Annual Average DDD in Bottom Deposits in the Upper Houston Ship Channel

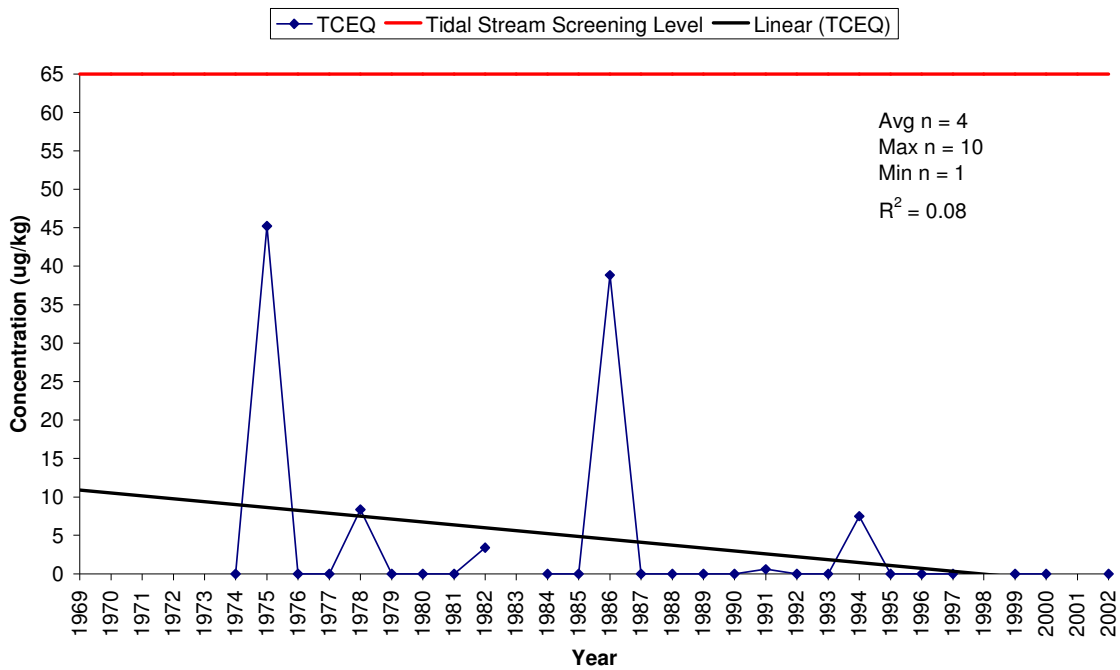
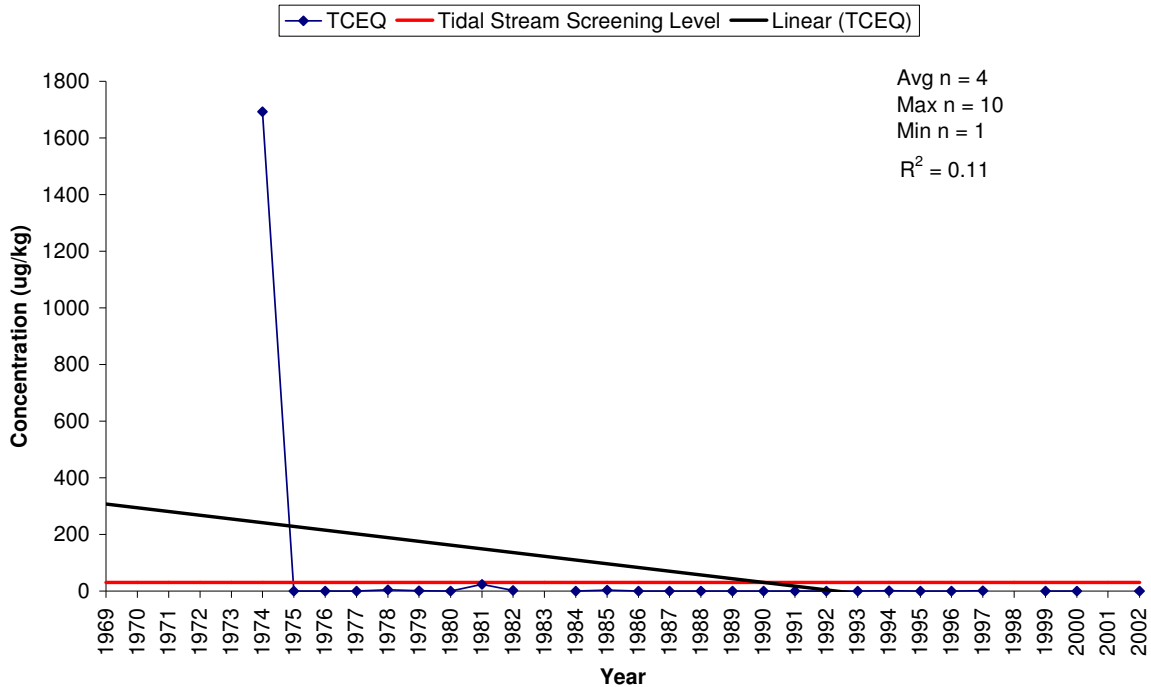


Figure 4.2.2.10. Annual Average DDE in Bottom Deposits in the Upper Houston Ship Channel



**PCB**

When released into water, a small amount of PCBs may remain dissolved, but most adhere to organic particles, sediments and other solids. Photolysis appears to be the only viable chemical degradation process that PCBs undergo in water. High surface sediment concentration can lead to the exchange of PCBs from sediment to water. In addition, the more water soluble, lower chlorinated congeners are predominantly in the dissolved state in the water column and can readily partition into the vapor phase. PCBs are also highly bioconcentrated in fish. Fish exposed to PCBs for several weeks can develop various kinds of health effects including anemia, acne-like skin conditions, and liver, stomach, and thyroid gland lesions. Certain benthic organisms (shrimp, clams, crabs) can accumulate PCBs from the intake of phytoplankton and zooplankton, which contain higher levels of PCBs than most water. Greater accumulation of PCBs will occur in fatty tissues as apposed to muscles or whole body of aquatic organisms.

Of the seven new study areas, the Christmas Bay/Bastrop Bayou Complex, Galveston Channel, Lower Houston Ship Channel, Intracoastal Waterway East, Trinity River, and West Bay lacked sufficient data (less than ten years) to discern a trend. Of interest is the trend graph for the Upper Houston Ship Channel (Figures 4.2.2.11).

Table 4.2.2.7. Summary of Annual Trends of Total PCB in Sediment.

Study Area	Trend Direction	R <sup>2</sup> Value
Christmas Bay/Bastrop Bayou	Insufficient Data	--
Galveston Channel	Insufficient Data	--
Lower Houston Ship Channel	Insufficient Data	--
Upper Houston Ship Channel	No Trend	0.10
Intracoastal Waterway East	Insufficient Data	--
Trinity River	Insufficient Data	--
West Bay	Insufficient Data	--

The TCEQ PCB in Sediment Tidal Stream Screening Level of 190.0 ug/kg was applied to the Upper Houston Ship Channel trend graph. For the most part (63 out of 94 samples), concentrations in the Upper Houston Ship Channel were below the detection limit. 14 of the 94 samples exceeded screening levels. Locations where those were collected include San Jacinto Park, the confluence with Sims Bayou, Goose Creek, the Turning Basin, and the confluence with Greens Bayou.

Screening levels were developed in 2002 and are meant to be used as a point of reference only. The Status and Trends data should not be used in the context of regulatory exceedances.

Figure 4.2.2.11. Annual Average Total PCB in Bottom Deposits in the Upper Houston Ship Channel

