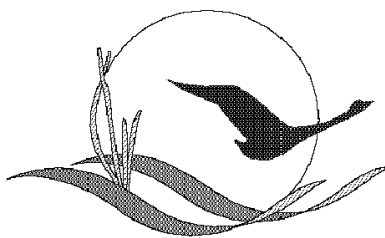


# **Chesapeake Bay Basin Toxics Loading and Release Inventory**

**May 1999**

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## Executive Summary

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### I. WHAT IS THE PURPOSE OF THIS INVENTORY?

This Toxics Loading and Release Inventory is one of many tools the Chesapeake Bay Program is using to set more targeted source reduction and pollution prevention goals to reduce and eliminate toxic impacts in the Bay. The overall goal of the *1994 Chesapeake Bay Basinwide Toxics Reduction and Prevention Strategy* is “a Chesapeake Bay free of toxics by reducing or eliminating the input of chemical contaminants from all controllable sources to levels that result in no toxic or bioaccumulative impact on the living resources that inhabit the Bay or on human health.”

To address that goal, the Bay Program has been following these steps (Figure 1):

1. Identifying areas of the Bay impacted by toxics.
2. Determining chemicals causing the toxic impacts.
3. Determining the origin of those chemicals.
4. Implementing management actions to reduce inputs of those chemicals to levels that will result in no toxic or bioaccumulative impacts on the Bay’s living resources or on human health, based on available data and current state of science.

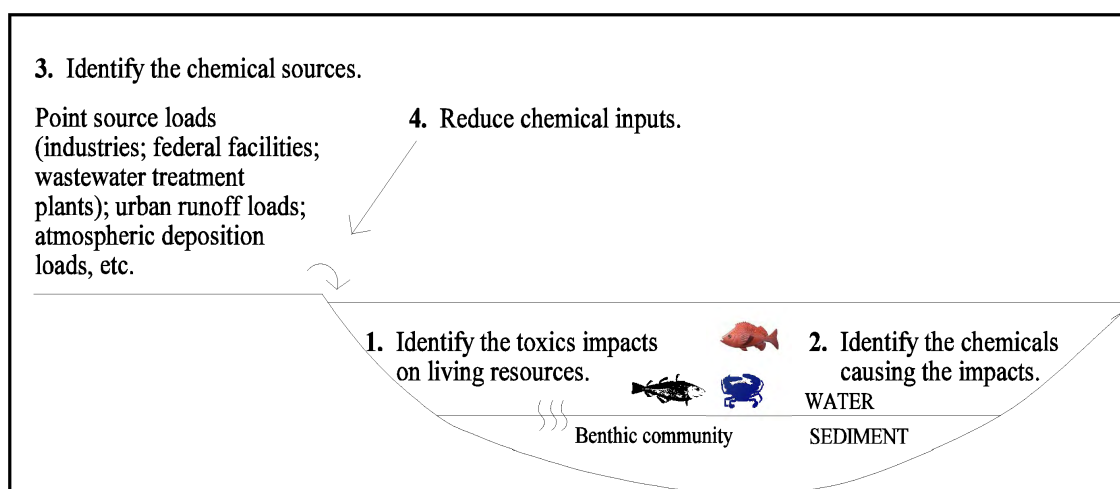


Figure 1. Chesapeake Bay Program process for managing chemical contaminant-related problems in the Bay and its rivers. This figure illustrates that the loading data reported in this inventory are only one piece of the overall toxics management picture. The inventory must be used in conjunction with data on toxics impacts and impairing chemicals in order to identify sources to control.

Since the signing of the 1994 strategy, the Bay Program has made significant progress in identifying toxic impacts in the Bay and chemicals causing the impacts. In early 1999, the Bay Program completed its characterization of toxic impacts in all tidal rivers of the Bay. This toxics characterization will supplement existing characterizations carried out by Bay Program partners and will provide a scientifically-based description of the distribution and extent of chemical contaminant impacts in the Bay. This characterization and other state efforts have identified chemicals which cause problems in localized areas of the Bay's rivers. In addition, the Bay Program has developed a Chesapeake Bay Toxics of Concern List of chemicals which cause, or have the potential to cause, adverse impacts on the Bay system.

**The information on impacts and chemicals causing impacts, coupled with this updated 1999 Chesapeake Bay Basinwide Toxics Loading and Release Inventory, will enable managers, scientists, and stakeholders to target their toxics reduction and prevention activities toward specific sources and chemicals in impacted areas of the Bay.**

This inventory can be used by managers, scientists, and the public in the following ways:

- ▶ Scientists, managers, and stakeholders can use this inventory, coupled with the toxics characterization, to set reduction targets for sources of chemicals causing toxic impacts in the Bay's tidal rivers.
- ▶ Managers can use the assessment of the relative importance of point and nonpoint sources of chemical contaminants to better target their management programs to the most important sources.
- ▶ Scientists can use this inventory to

identify the greatest data needs to improve future loads estimates.

- ▶ The public can use this inventory to learn about their waterbodies of interest – the types of chemicals entering these waters, the magnitude of the loads, and chemical sources. This information, coupled with the toxics characterization of these waters, will help the public identify how and when to act to reduce chemical loads to these waters.

This inventory reports chemical contaminant loads to the Bay and its rivers but does not report what the loads mean to the Bay's living resources or which specific sources and chemicals are causing impacts. A big load of a chemical contaminant does not necessarily mean a big impact, nor does a small load always indicate a small impact. A big load of chemical contaminants from a particular source also does not mean that the source is uncontrolled. For example, point source dischargers may be in compliance with their permits, but may still produce a substantial load to the Bay and tidal rivers. This is often the case with large flow facilities (i.e., wastewater treatment plants) that emit a very low concentration of a chemical into the Bay and tidal rivers, but their flow is so large that it results in a large load. As stated previously, this inventory can be used in conjunction with the toxics characterization to help managers target management actions toward specific geographic areas, chemicals, and sources.

*Toxicity of a chemical depends on many factors such as the concentration, chemical/physical form, and persistence of the chemical; the chemical/physical properties of the waterbody it is entering (i.e., pH, sediment type, etc.); and the type and life stage of the living resources exposed to the chemical.*

## **II. WHAT IS THE FOCUS FOR THIS INVENTORY?**

### *Loads and Releases*

This inventory reports both loadings and releases to the Bay watershed. Loadings are estimates of the quantity of chemical contaminants that reach the Bay and tidal rivers, from sources such as point sources discharging into the Bay or its rivers, urban runoff, atmospheric deposition on the Bay or its rivers, shipping and boating, and acid mine drainage. Releases are the estimates of the quantity of chemical contaminants emitted to the Bay's watershed that have the potential to reach the Bay. The only release information in this inventory is for pesticide usage.

### *Loads to Tidal Rivers and Bay*

The Chesapeake Bay has a direct connection with the Atlantic Ocean. Because of the ocean tides, saltwater from the Atlantic is mixed in the Bay with freshwater derived from land runoff. The part of the Bay and its rivers that is influenced by the tide is referred to as the "tidal Bay" and "tidal rivers." Moving upstream, there comes a point at which the rivers are no longer influenced by the ocean tide. The portions of the rivers that are not under the influence of the tide is referred to as "non-tidal." The boundary between the non-tidal and tidal portions of a river is called the "fall line." The fall line is the physiographic boundary representing the natural geographic break between the non-tidal and tidal regions of the Bay watershed. For example, in the Potomac River, the fall line is at Great Falls.

The tidal portions of rivers appear to be efficient traps for chemical contaminants, which may be a reason why only low levels of chemical contaminants are detected in the

Bay. This inventory mainly reports chemical contaminant loads to the Bay and its tidal rivers, as opposed to non-tidal waters, because tidal waters are the focus of the Bay Program's toxics efforts. The sites of many of the known toxics problems are in tidal waters and most of the urban areas and toxics-related land use activities are adjacent to tidal waters. However, it is important to note that non-tidal waters -- above the fall line -- are also sources of chemical contamination. Chemical contaminant loads can enter the Bay and its rivers above the fall line (non-tidal waters) or below the fall line (tidal waters). Measurements taken at the fall line are used to represent the fraction of upstream loads (whether from point or nonpoint sources) that make it to the tidal waters. Upstream sources can originate from point sources such as industries, federal facilities (e.g., military bases), and wastewater treatment plants or nonpoint sources such as agricultural or urban runoff. In this inventory, chemical contaminant loads entering the rivers above the fall line are reported for point sources, urban runoff, and acid mine drainage only. Loads to the tidal rivers, below the fall line, are reported for point sources, urban runoff, atmospheric deposition, and shipping and boating spills. (Figure 2)

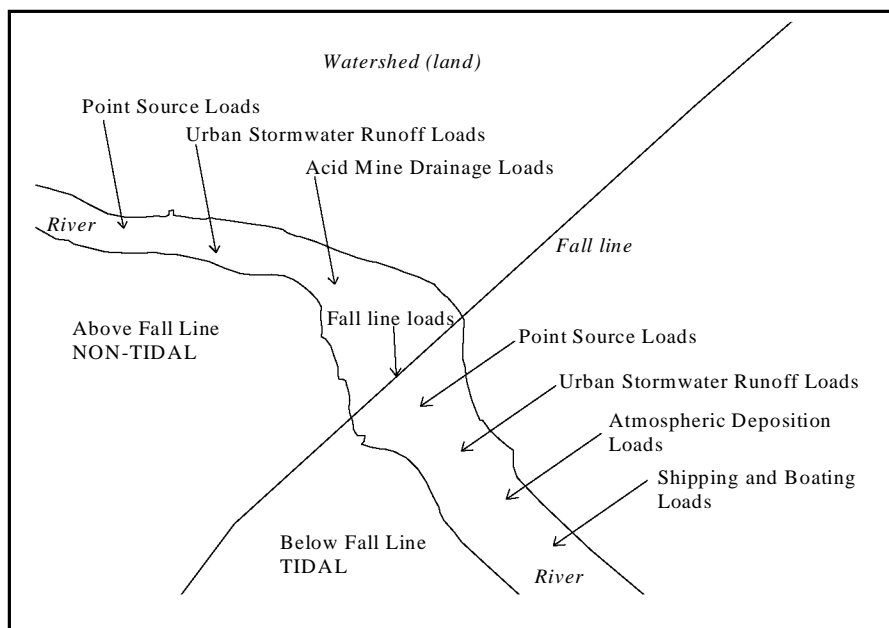


Figure 2. The sources of chemical contaminant loads to the Bay, above the fall line and below the fall line, reported in this inventory.

### *Chemicals Reported*

Loadings are reported for chemicals on the Chesapeake Bay Toxics of Concern List (TOC) and the Chemicals of Potential Concern List. These chemicals cause or have the potential to cause adverse effects on the Bay's living resources. Other chemicals that are not on these lists, but having very high loads, are also reported. The TOC list represents inorganic contaminants such as metals (copper, lead, mercury) and organic contaminants such as polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Metals come from both point and nonpoint sources from a variety of activities. PAHs come from the combustion of fossil fuels and from oil and grease used in cars. PCBs were used as fire retardants and can be found in older electric transformers and other machinery. Although PCBs are banned, they are still found in the environment and we still report them where found.

### *Controlling Toxic Inputs: Concentrations Versus Cumulative Loads*

Historically, the regulatory focus for controlling toxic inputs to waterbodies has been on controlling concentrations at the end of a pipe, or point sources, with very little focus on nonpoint sources. Discharges of chemicals to the Bay and its rivers are allowed if they fall below the levels thought to cause impacts on the Bay's living resources. Managing concentrations of contaminants in this way may be appropriate for those chemicals that do not linger in the water or sediment, either because they break down or they are in well-flushed systems. In this case, living resources may not be exposed to these chemicals for a sufficient amount of time to cause an impact. However, for persistent chemicals in poorly-flushed systems (i.e., harbors), managing the **cumulative load** of those chemicals may be more appropriate. In this case, persistent chemicals may accumulate in the water or sediment in a poorly-flushed system and result in ambient concentrations that pose a greater threat to the living resources exposed to them.

Nationally, we are starting to see a shift from managing end-of-pipe concentrations to controlling cumulative loads from both point and nonpoint sources through state implementation of the *Clean Water Act's* Total Maximum Daily Loads program. This approach complements and enhances traditional approaches of controlling chemical concentrations exiting pipes by addressing the ambient concentration of contaminants (resulting from all sources) to which living resources may be exposed. From the perspective of the Bay's living resources, what matters is the concentration of a chemical to which they are exposed, what form it is in, and how long it persists. Some of these chemicals persist and

accumulate in the environment, while some degrade or are flushed out of the Bay and tidal rivers. Some may interact with each other to become more or less toxic. The physical and chemical properties of the living resource's habitat may impact the toxicity of the chemicals as well. By managing the loads, we can take into account impacts that may result from cumulative loads coming from many different sources, synergistic effects of multiple contaminants and other factors that may affect toxicity. This approach recognizes that all sources (not just the largest sources) may play a part in causing an impact and, therefore, may play a part in reducing or eliminating the impact.

As the Bay Program and states evolve toward a more loads-based system for toxics management, inventories such as this one will become more important in helping managers to target their source reduction efforts in impacted areas. Data collection efforts will need to evolve to reflect this evolution by improving measurements that allow for easier and more certain loads estimates.

### **III. WHAT IMPROVEMENTS HAVE BEEN MADE SINCE THE 1994 INVENTORY?**

***Point Source Loads*** in this inventory are reported for industries, federal facilities, and municipalities discharging a flow of 0.5 million gallons per day or larger into the Bay and are based on measured data from sources such as the Permit Compliance System. In the 1994 inventory, point source loads relied more heavily on the national Toxics Release Inventory (TRI). The TRI database is of limited value in estimating point source loads (or releases) to the surface waters of the Bay and tidal rivers because data are based on estimates rather than measured values; the database represents only a small fraction (approximately 5%) of all point sources; and releases to surface waters appear to be overestimated. Estimates of point source loads have been improved by including nearly twice as many facilities as the 1994 inventory. Estimates for facilities above and below the fall line are based on more monitored data sources collected over a consistent period of time for more chemicals.

***Urban Runoff Loads*** are from chemical contaminants on urban land (both impervious and pervious surfaces) that are transported to the Bay and its rivers by stormwater runoff. These estimates are much improved because they are based on recent stormwater monitoring data collected by each jurisdiction in the watershed in support of the National Pollutant Discharge and Elimination System stormwater permitting program. Previous estimates were based on nationwide data, mostly from the early 1980s. Estimates are reported from above the fall line and below the fall line.

***Atmospheric Deposition Loads*** are loads from chemical contaminants in the air that are deposited onto the Bay and its tidal

rivers. These estimates are updated and expanded using recent field measurements and improved theoretical understanding of deposition processes. Volatilization of organic contaminants from the surface waters to the air is considered for the first time in calculating a “net” atmospheric loading to the Bay and tidal rivers. Initial estimates of the contribution of urban areas to atmospheric deposition loads to the Bay and tidal rivers also are reported. Only loads below the fall line are reported. The TRI database for industrial air releases was not included in this inventory, as it was in 1994, since the improved and expanded atmospheric loadings data (below the fall line) are based on measured data and are a much better representation of loads than the TRI data estimates of releases.

***Shipping and Boating Loads*** are chemical contaminants entering the Bay and tidal rivers from boating-related spills. These estimates are improved because they are based on additional data sources; recovery data were used to calculate net spill quantities; and spills were more accurately located based on better geographic data. Only loads to the Bay and tidal rivers, below the fall line, are reported.

***Acid Mine Drainage Loads*** are chemical contaminants, typically metals, from active and abandoned coal mines. These loads are reported for the first time, based on a comprehensive literature synthesis of contaminant levels found in acid mine drainage entering streams in the upper portion of the watershed. These loads are above the fall line, where the mines are located.

***Fall Line Loads*** represent the aggregate of point and nonpoint sources above the fall line that make it to the tidal waters. These loads are much improved due to upgrades in

analytical methods and load estimation techniques. Loads from the Susquehanna and James rivers are updated and new loads are reported for the Potomac, Patuxent, Choptank, Nanticoke, Pamunkey, Mattaponi, and Rappahannock rivers.

***Pesticide Releases*** to the watershed were based on much improved pesticide usage data from a variety of national databases and data from state surveys and pesticide experts collected over a consistent period of time. However, pesticide usage was not translated into loads.

***Relative Importance of Sources*** to the Bay and its tidal rivers is reported in this inventory for the first time to provide managers, scientists, and the public with information on the most important sources of estimated chemical contaminant loads. Loadings from sources with the most widespread and available data were reported from point sources, urban runoff, and atmospheric deposition. Shoreline erosion loads of several metals were estimated for this “relative importance of sources” chapter, but were not included as a separate chapter because data are so sparse. Upstream contaminant loads to the tidal waters from all sources are represented by the fall line loadings data.

***Mass Balance of Chemical Contaminants*** is a new section of the inventory which provides (1) a gross check and balance on whether or not loadings estimates are consistent and realistic, (2) an idea of the fate of contaminants in the Bay and its tributaries, (3) a management tool for predicting results from load reductions, and (4) a consistent way to identify key data gaps and uncertainties that need to be addressed for management/scientific purposes.

#### IV. WHAT ARE THE LIMITATIONS OF THE 1999 INVENTORY?

These loading and release data represent the best data available to date. However, there are still many uncertainties and limitations of the data which are highlighted at the end of each chapter. Where feasible, confidence levels in the data have been quantified. It is important to note that most of the data that were used to calculate loads were not collected with that purpose in mind. Many problems are inherent in these types of calculations including a general lack of quality data, incomparability of chemical measurements and forms from each source category, and incomplete reporting of the various sources as discussed in the individual loading chapters. Although this inventory is much improved over the 1994 inventory, it is still a work in progress with some limitations listed below.

*The inventory is not comprehensive:*

This updated inventory, although more complete than the 1994 inventory, is not a comprehensive accounting of all loads of all chemical contaminants to the Bay and its tidal rivers. Loads are reported for only a subset of all chemicals released in the watershed. Additionally, some sources of chemical contaminant loads are not quantified or completely accounted for as described below.

- ***Point source loads*** are only estimated for *major* facilities (facilities with a flow of 0.5 million gallons per day or greater) and have not been estimated for the approximately 3,700 minor facilities in the watershed because data from the Permit Compliance System are often incomplete for these smaller facilities.



- ▶ ***Atmospheric deposition loads*** are only those deposited directly to the water. The loads that are carried off the watershed (i.e., the land) into the Bay and tidal rivers by stormwater runoff are not accounted for in the atmospheric deposition loads category. However, these loads from the upper portion of the watershed, above the fall line, are partially accounted for in the fall line loads estimates for those chemicals that were measured at the fall line. Loads from the lower part of the watershed are partially accounted for by the below fall line urban runoff estimates.
- ▶ ***Agricultural loads*** (i.e., pesticides from cropfields, metals from poultry production), as in the 1994 inventory, are not reported as a separate source category in this inventory because very little data on pesticide loads are available and it is difficult to translate pesticide usage data into loads. However, loads from agricultural lands upstream are accounted for in the fall line loadings estimates for those chemicals that were measured at the fall line. Below the fall line, loadings for select pesticides are accounted for in the atmospheric deposition loadings data.
- ▶ ***Groundwater loads*** are not reported as a separate source category and are only accounted for in the fall line loadings data for those chemicals measured at the fall line. There are no available data to estimate groundwater loads below the fall line.
- ▶ ***Natural background loads*** have not been quantified as a separate source category because data were not available to determine the portion of loads originating from natural processes such as mechanical or chemical weathering of

rock, which results in metal loads. The shoreline erosion loads estimates for select metals in the “relative importance of sources” chapter provides a partial accounting of natural background loads.

*Point source loads estimates are uncertain:*

Point source loads are important, but uncertainty in loading estimates is large in some cases. Loads may not have been adjusted to account for pollutants that are present in a facility’s intake water. Additionally, reporting programs in which data were collected were not set up with the objective of calculating loads, but rather for determining compliance with regulated parameters in discharge permits. For certain organic contaminants -- all PCBs, pesticides, and most PAHs -- values were reported as below the detection limits. With the data available for these organic contaminants, the load may be as low as zero or as high as the detection limit multiplied by the flow. Using zero for organic contaminants could grossly underestimate the load, but using the high value for organic contaminants could grossly overestimate the load. This uncertainty is not the case for the metals data, since most metals are above the detection limit.

To get an idea of the magnitude of loads of organic contaminants from point sources in the Potomac river watershed, PCB concentrations in wastewater treatment plant effluent in the New York/New Jersey Harbor estuary were used to estimate loads. These PCB concentrations were measured at much lower detection limits than used in this inventory. Based on this analysis, if lower detection limits were used to measure end-of-pipe concentrations of organic contaminants, the estimated point source loads may be substantial (up to 60% of the total PCB load entering the tidal Potomac river) but still less than the high load in the

range described above.

*The contribution of specific upstream sources to tidal loads are unknown:*

More information is needed regarding the fate, transport, and attenuation processes of chemical contaminants above the fall line, in order to determine the important contributors of upstream sources of chemical contaminants to the Bay and its tidal rivers.

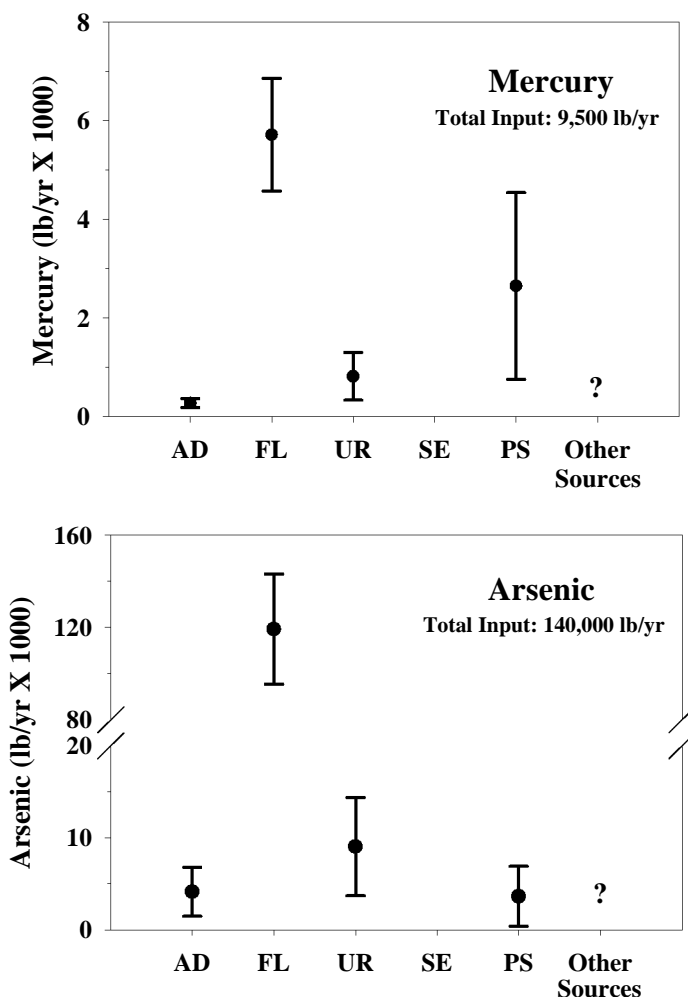
*Updated loadings cannot be compared to the 1994 inventory to assess trends:*

The 1999 inventory is an important step forward in the Bay Program's efforts to compile a comprehensive, high quality inventory of point and nonpoint source loads to the Bay. The Bay Program has made significant improvements to the previous 1994 inventory by increasing the sources quantified and improving analytical and loadings estimate techniques. Since the loadings estimates in this inventory include many more sources and new and improved analytical and loadings estimation techniques, they cannot be compared to those from the 1994 inventory to assess trends. Also annual fluctuations in meteorology affect our ability to compare fall line loadings and nonpoint source loads from year to year. Therefore, this inventory does not report on loadings trends since the 1994 inventory.

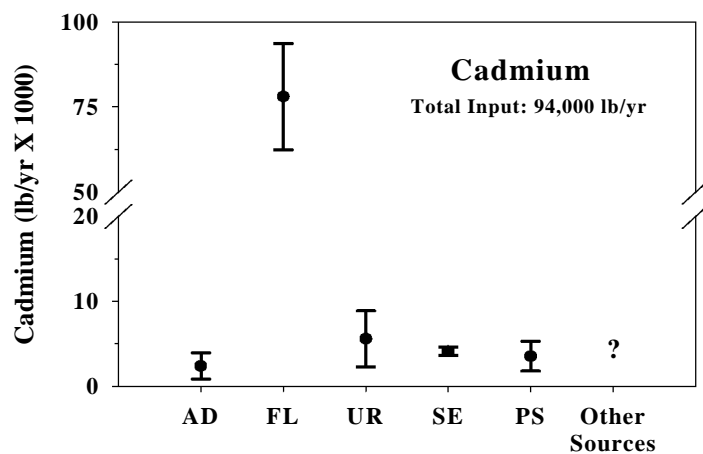
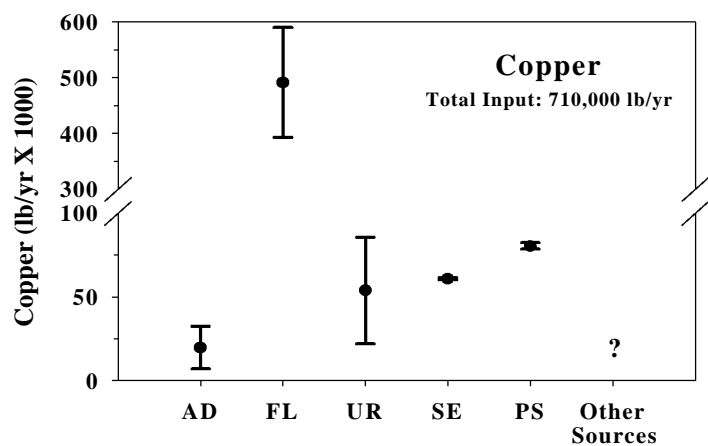
## V. MAJOR FINDINGS

Sources of contaminants to the Bay and its tidal rivers vary by chemical and by land use and activities on the watershed. Through analysis of loadings data estimated using data collected between 1990 and 1997, some clear patterns are observed:

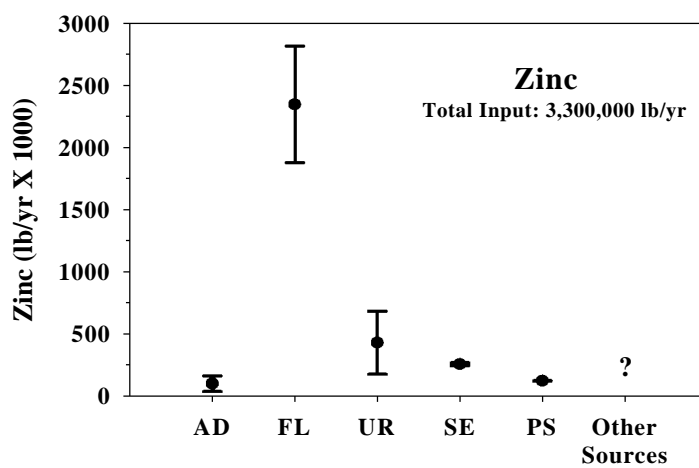
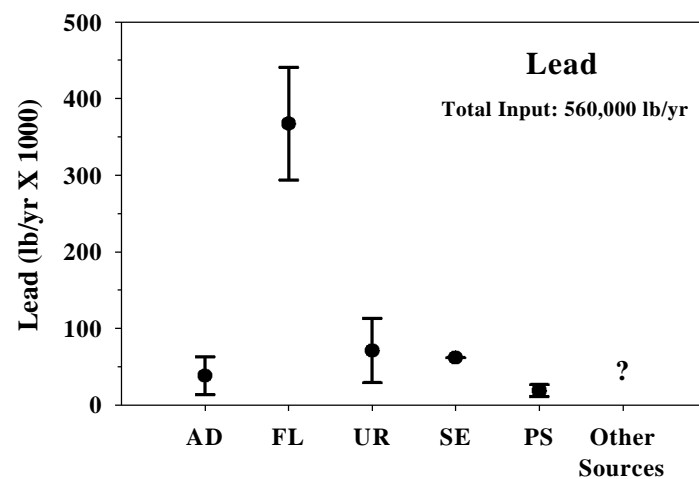
- ▶ **Upstream sources, from either point or nonpoint sources to non-tidal waters above the fall line, provide substantial loads of metals to the Bay and tidal rivers.** Fall line loads account for between 60% for mercury to 87% for arsenic of total loads to the Bay and its tidal rivers.
- ▶ **Point sources below the fall line account for a substantial load of metals, such as copper and mercury, to the entire Bay and its tidal rivers.** Point source loads of copper and mercury account for 11% and 28% of total loads respectively.



Total loads of mercury and arsenic to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

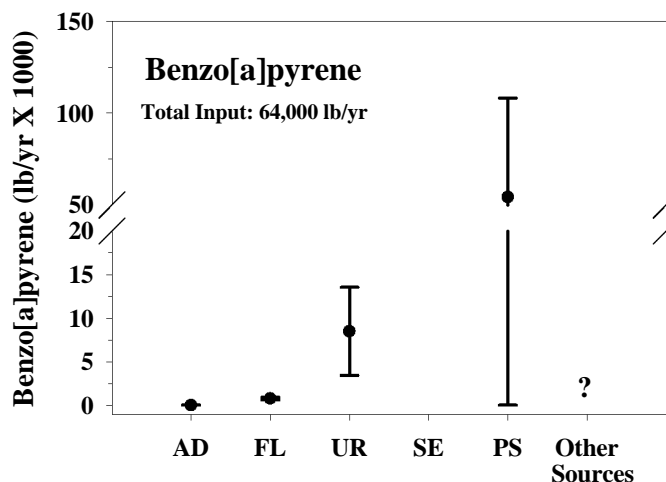


Total loads of copper and cadmium to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. For copper, the variability in the shoreline erosion estimate is smaller than the symbol representing the average.

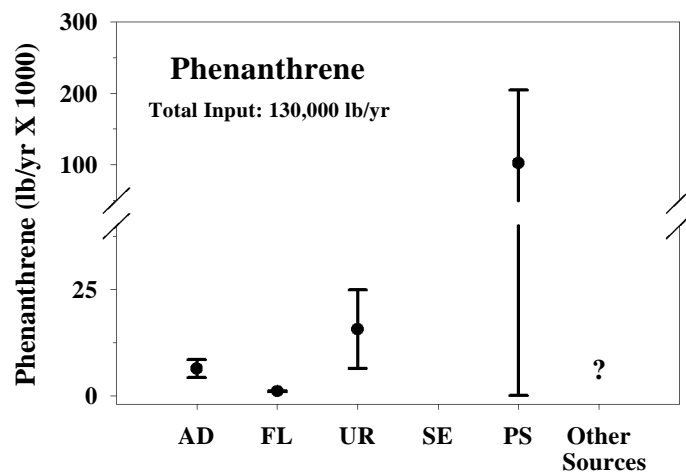
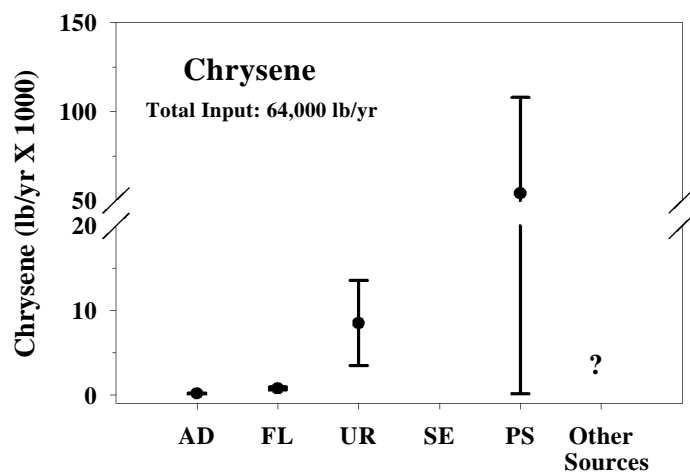


Total loads of lead and zinc to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. For lead, the variability in the shoreline erosion estimate is smaller than the symbol representing the average, and for zinc, the variability in the point source estimate is smaller than the symbol representing the average.

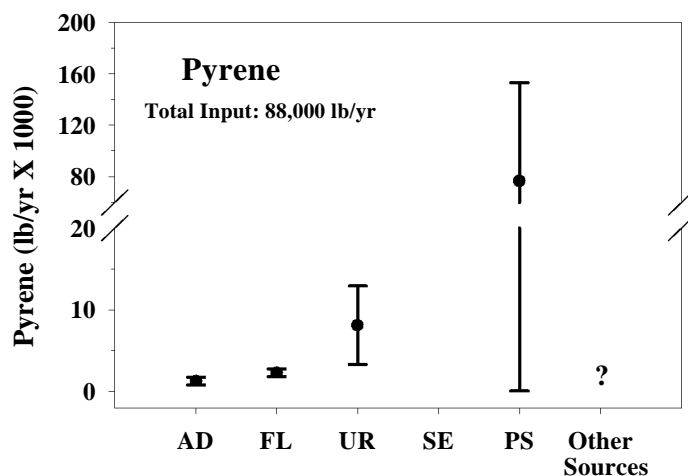
- ▶ **Point sources below the fall line are important loads to the different tidal rivers** and can account for up to approximately 10% of the total quantified load for some metals. Organic contaminant loads are very uncertain at this time, but data suggest that point source loads of PCBs can be substantial and should be the target of additional monitoring and analysis.
- ▶ **Urban runoff below the fall line is a substantial source of select organic contaminants (PAHs) to the Bay and tidal rivers.** Given that point source loads estimates are highly uncertain (as indicated by the large uncertainty bar in the figures), urban stormwater runoff is the most substantial known source of PAH loads to the Bay and tidal rivers. Urban runoff loads of PAHs to individual rivers are also substantial as illustrated in the Patuxent River figure.



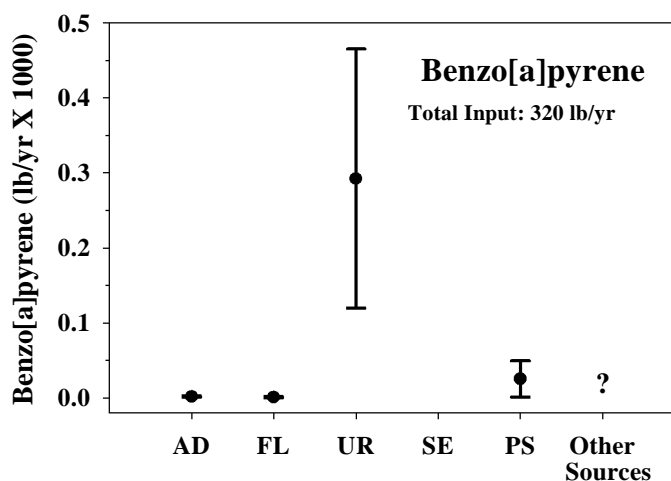
Total loads of the PAH benzo[a]pyrene to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the atmospheric deposition and fall line estimates is smaller than the symbol representing the average.



Total loads of the PAHs chrysene and phenanthrene to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. For chrysene, the variability in the atmospheric deposition and fall line estimates is smaller than the symbol representing the average.



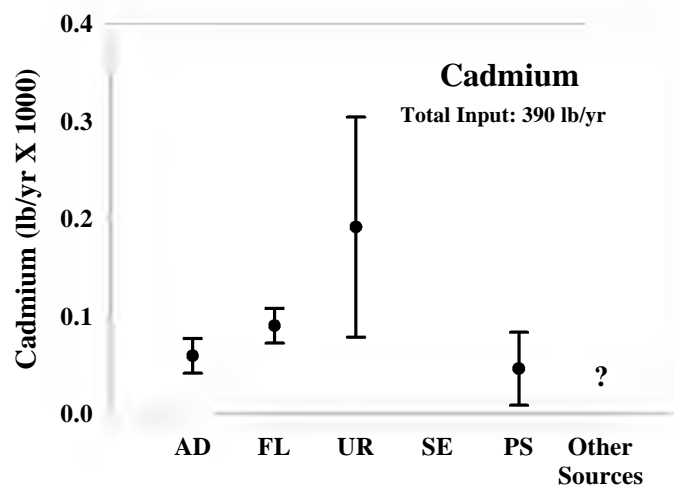
Total loads of pyrene to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.



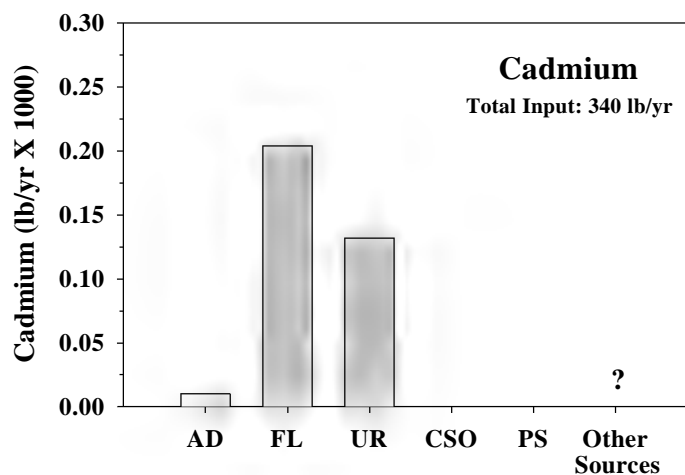
Total loads of benzo[a]pyrene to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the atmospheric deposition and fall line estimates is smaller than the symbol representing the average.



- **Urban runoff below the fall line is a substantial source of metals to the Patuxent and Anacostia Rivers** as illustrated in the figures summarizing cadmium loads. Ranges were not calculated for the Anacostia River loads due to a lack of data (and lack of uncertainty reporting) from the different data sources.



Total loads of cadmium to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.



Total loads of cadmium to the tidal Anacostia River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); combined sewer overflow (CSO); and point sources (PS). Point source loadings were not reported. Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. Uncertainties were not calculated due to a lack of data and reported ranges.

- ▶ **Point sources of organic contaminants (PAHs and PCBs) are highly uncertain** because of measurement methods currently used for permit compliance monitoring; therefore, loads are largely unknown.
- ▶ **Loadings are dependent on land use characteristics on the watershed and not the size of the watershed.** For example, the Anacostia River watershed, a relatively small urban watershed, produces 12 times the loads of the metal, lead, than any of the other major river watersheds.

Trace metal total watershed yields for selected tributaries of the Bay.

	Susquehanna	Potomac	James	Patuxent	Anacostia
Copper	4.05	3.90	3.95	1.75	13.1
Cadmium	0.61	0.61	0.35	0.16	0.46
Lead	2.44	4.17	3.15	1.54	42.9
Mercury	0.052	0.084	0.055	0.018	0.026

Units: lb/km<sup>2</sup>-yr.

- ▶ **Below the fall line, atmospheric deposition loads increase in areas of the Bay and tidal rivers adjacent to urban areas.**
- ▶ **Shipping and boating-related spills from 1990 - 1996 resulted in 154 substances such as jet fuel, gasoline, diesel oil, asphalt, and PCBs being loaded into Bay and tidal rivers in 4,736 recorded incidents.** Most of the materials were spilled in the mainstem Bay or in areas such as the West Chesapeake Basin and the tidal James River where large port, industrial, or military installations are located.
- ▶ **Acid mine drainage has impacted 1100 miles in 158 streams in the Chesapeake watershed according to the 1996 state 303(d) reports.** The causes cited for water quality degradation from acid mine drainage are related to low pH and/or metals contamination (iron, manganese, and aluminum).
- ▶ **Pesticide loads to the Bay and tidal rivers are largely unknown. 7,749,000 pounds of pesticide active ingredient were applied to the four major crops in the watershed in 1996:** corn, soybeans, small grains, and alfalfa. Some of these pesticides have been detected in surface and groundwater. Studies are needed to quantify the fraction of pesticides that end up in the Bay and its tidal rivers.

## **VI. WHAT ACTIONS CAN BE TAKEN TO IMPROVE THE INVENTORY?**

This inventory represents the most comprehensive loadings analysis for chemical contaminants compiled to date for the Bay and tidal rivers. This inventory can serve as a useful planning tool for directing future management and monitoring activities in the watershed. Specific recommendations for improving loads estimates for each source are detailed in the individual chapters of this inventory. Some overall recommendations for improving the inventory are:

- ▶ Continue to increase the number of accountable sources and improve analytical and loads estimation techniques.
- ▶ Improve the point source loadings estimates, particularly for the organic contaminants, by obtaining more information on wastewater characteristics and by considering better methods for detecting organic contaminants.
- ▶ Determine the important upstream sources of chemical contaminants to the Bay and tidal rivers by increasing our understanding of contaminant transport and attenuation processes.
- ▶ Quantify other potentially significant sources of loads from agricultural lands and groundwater. Specific studies to quantify the fraction of pesticides used that are loaded into the Bay and its tidal rivers would be particularly useful.

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## Acknowledgments

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Special recognition goes to the Toxics Subcommittee's Directed Toxics Assessment Workgroup and the Toxics Subcommittee Fellows for their input into the development and review of this report. This inventory can be found on the Chesapeake Bay Program web page at <http://www.chesapeakebay.net> or contact the Bay Program Office at 1-800 YOUR BAY.

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## DESCRIPTION OF INVENTORY CHAPTERS

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The inventory is divided into the following six sections:

- ▶ ***Executive Summary*** summarizes the purpose of this inventory, improvements since the 1994 inventory, limitations of loading and release estimates, and major findings, with an emphasis on comparing the relative contributions of point and nonpoint sources of metals and organic contaminants entering the Bay and its major tidal tributaries.
- ▶ ***Loadings*** are estimates of the quantity of chemical contaminants that reach the Bay waters. These loadings can enter the Bay above the fall line or below the fall line. The fall line is the physiographic boundary between the Piedmont and the Atlantic Coastal Plain provinces, representing the natural geographic break between the tidal and non-tidal regions of the Bay watershed.
  - Loads to the non-tidal portions of the Bay's and its rivers (above the fall line) are reported from acid mine drainage.
  - Loads to the tidal portion of the Bay and its rivers (below the fall line) are reported from atmospheric deposition and shipping and boating.
  - Both above the fall line (non-tidal) loadings and below the fall line (tidal) loadings are reported for point sources and urban runoff.
- ▶ ***Fall Line Loadings*** estimates represent the aggregate of chemical contaminant loads from upstream point and nonpoint sources that make their way to the tidal portion of the Bay and its rivers. These estimates are based on measurements taken at the fall line.
- ▶ ***Releases*** are estimates of the quantity of chemical contaminants emitted to the Bay's watershed that have the potential to reach the Bay. Only pesticide usage data are summarized in this section. While not a direct measure of loads, the pesticide usage data can provide inference about the quantity of pesticides released onto the watershed, a fraction of which may end up in the groundwater or surface waters of the Bay.
- ▶ ***Relative Importance of Point and Non-Point Sources of Chemical Contaminants to Chesapeake Bay*** and its rivers is reported in this inventory for the first time to provide managers, scientists, and the public with information on the most important sources of chemical contaminant loads. Loadings from sources with the most widespread and available data were reported from point sources, urban runoff, atmospheric deposition, and shoreline erosion (where available). Upstream contaminant loads to the tidal waters from all sources are represented by the fall line loadings data.
- ▶ ***Mass Balance of Chemical Contaminants*** is a new section of the inventory which provides (1) a gross check and balance on whether or not loadings estimates are consistent and realistic, (2) an idea of the fate of contaminants in the Bay and its tributaries, (3) a management tool for predicting results from load reductions, and (4) a consistent way to identify key data gaps and uncertainties that need to be addressed for management/scientific purposes.

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## CHAPTER 1 - Point Source Loadings

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### INTRODUCTION

The purpose of this chapter is to present data on chemical contaminants discharged to surface waters by point sources located within the Chesapeake Bay watershed. Point sources are end-of-pipe discharges from industrial, municipal, or federal facilities. The information presented herein is an assimilation of data obtained from EPA's National Pollution Discharge Elimination System (NPDES) Permit Compliance System (PCS) and other effluent reporting or sampling programs performed by the Bay jurisdictions. Data was obtained in terms of chemical effluent concentration and discharge flows, and analyses were performed by the Chesapeake Bay Program Office to calculate total estimated discharged load. The loads are presented as pounds of chemical discharged per year. Analyses were performed after consultation with the Chesapeake Bay Program's Toxic Subcommittee's Directed Toxic Assessment (DTA) Workgroup. The data sources, methodologies, and assumptions used to calculate discharged loads as well as the total estimated loads are presented in detail in the following sections of this chapter.

Three appendices accompany this chapter of the Toxics Loading and Release Inventory document. These appendices include Appendix A: List of chemicals and default detection limits, Appendix B: Loads of chemical categories by Standard Industrial Classification (SIC) codes, and Appendix C: Inventory of Point Source Loads by Facility. Appendix C is published separately from this document and is available from the Chesapeake Bay Program Office.

### TEMPORAL AND SPATIAL COVERAGE

There are approximately 4000 industrial, municipal, and federal point source dischargers within the Chesapeake Bay watershed. Of these, 316 are classified as currently operating "major" dischargers in the PCS database, discharging greater than 0.5 million gallons per day (MGD). This inventory includes 276 of these major point sources discharging to the Chesapeake Bay watershed for which data was available to evaluate loadings. Figure 1.1 shows the location of all 316 major point source dischargers in the Chesapeake Bay basin. However, only 228 facilities had data for the specified list of chemicals analyzed in this inventory (see "Chemicals Reported" section).

The loadings in this section include data from Pennsylvania, Maryland, Virginia, and the

### *Point Source Loadings*

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D.C. Blue Plains waste water treatment plant collected between 1992 - 1996. This range was chosen because it spans 5 years, the same as the (NPDES) monitoring program permit cycle. Every facility will have had their permit reissued at some point during this time frame.

The data sources for each state are summarized in Table 1.1. The complete inventory of point source loadings by facility, including all chemicals for which loads were calculated can be found in Appendix C.

Data from the Toxic Release Inventory (TRI) database are not included in this chapter. The data summarized in this report are estimated using actual measured concentrations, flows, and loadings whereas TRI data are estimated releases. Combining these very different data sources would introduce a large margin of error.

Table 1.1. Toxic Point Source data sources.

DATA CATEGORY	DATA SOURCES	VIRGINIA	MARYLAND	DISTRICT OF COLUMBIA (BLUE PLAINS)	PENN-SYLVANIA
<b>1. NPDES FORM 2C &amp; FORM A</b>	Hard copy* NPDES Application forms (2c & A) <sup>1</sup>	Collected when available and within the time frame (1992-1996)	Collected for 63 facilities which had a current (1992-1996) application form in their file.	NONE COLLECTED, Monthly operating reports collected instead	NONE COLLECTED, data is entered into PCS
<b>2. NPDES DMR</b>	A. NPDES DMR Reports from PCS <sup>2</sup>	COLLECTED	COLLECTED	COLLECTED	COLLECTED
	B. NPDES DMR Reports in hard copy			Monthly operating reports for Blue Plains WWTP were collected from the District of Columbia Dept. of Health.	
<b>3. VA TMP</b>	TMP (Toxics Management Program) <sup>3</sup>	Data from 5 regions were collected.	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE

\* Where data is listed as a hardcopy source, the CBPO loaded the data into an electronic database.

**<sup>1</sup> Application form descriptions**

Form 2c is required for any facility which discharges to waters of the U.S. This form includes information such as outfall descriptions, flows, latitude/longitude, and sources of pollutants within the facility. In addition, the form contains a list of 165 pollutants (the 126 priority pollutants as designated by US EPA, and standard water chemistry parameters). Which of those chemicals facilities are required to report is dependent on the type of facility. For every pollutant the facility has reason to believe is present in their discharge in concentrations of 10 ppb or greater, they must submit quantitative data. Form A is used for municipal WWTP. This form contains much of the same information as Form 2c with only 55 chemicals listed for which the facility may describe their wastewater.

*Limitations:* The main limitation of this data source is that for many parameters, only one sampling event occurred to obtain the data. Data are not originally in electronic format.

**<sup>2</sup> Permit Compliance System (PCS) data**

Discharge Monitoring Reports (DMR's) from the NPDES program are entered for the major dischargers and sometimes minor dischargers into this national database. This database contains data for all the states. PCS is the principal source of toxics data which was supplemented, where appropriate, by various data sources as described in the data source table.

*Limitations:* Database is lacking consistent temporal coverage, spatial data is inconsistently present, all fields in the database are text, missing data and errors are not uncommon, units are often not reported, or are inconsistently reported (ie., some chemicals are reported in both mg/l and ug/l), detection limits are not always present for a non-detect chemical, and data on minor facilities (discharging less than 0.5 MGD) may be lacking or insufficient.

**<sup>3</sup> Virginia TMP data**

The VA TMP is part of the NPDES program in Virginia. TMP data is generated from quarterly or semiannual sampling efforts depending upon the facility. The TMP is a separate program from NPDES which monitors compliance of 405 facilities in VA with biomonitoring and chemical analyses. The TMP monitors the same chemicals as those found on Form 2c. The TMP computerized database does not hold the chemical data which the facilities must report on their effluent. It only holds information on facility permit compliance. The chemical data remains in hard copy and is stored in the NPDES permit files at the regional offices in Virginia. This is the data which the CBPO has obtained for this loadings analysis.

*Limitations:* For some parameters only one sampling event occurred to obtain the data. Data are not originally in electronic format.



**CHESAPEAKE BAY BASIN MAJOR POINT SOURCE DISCHARGERS**

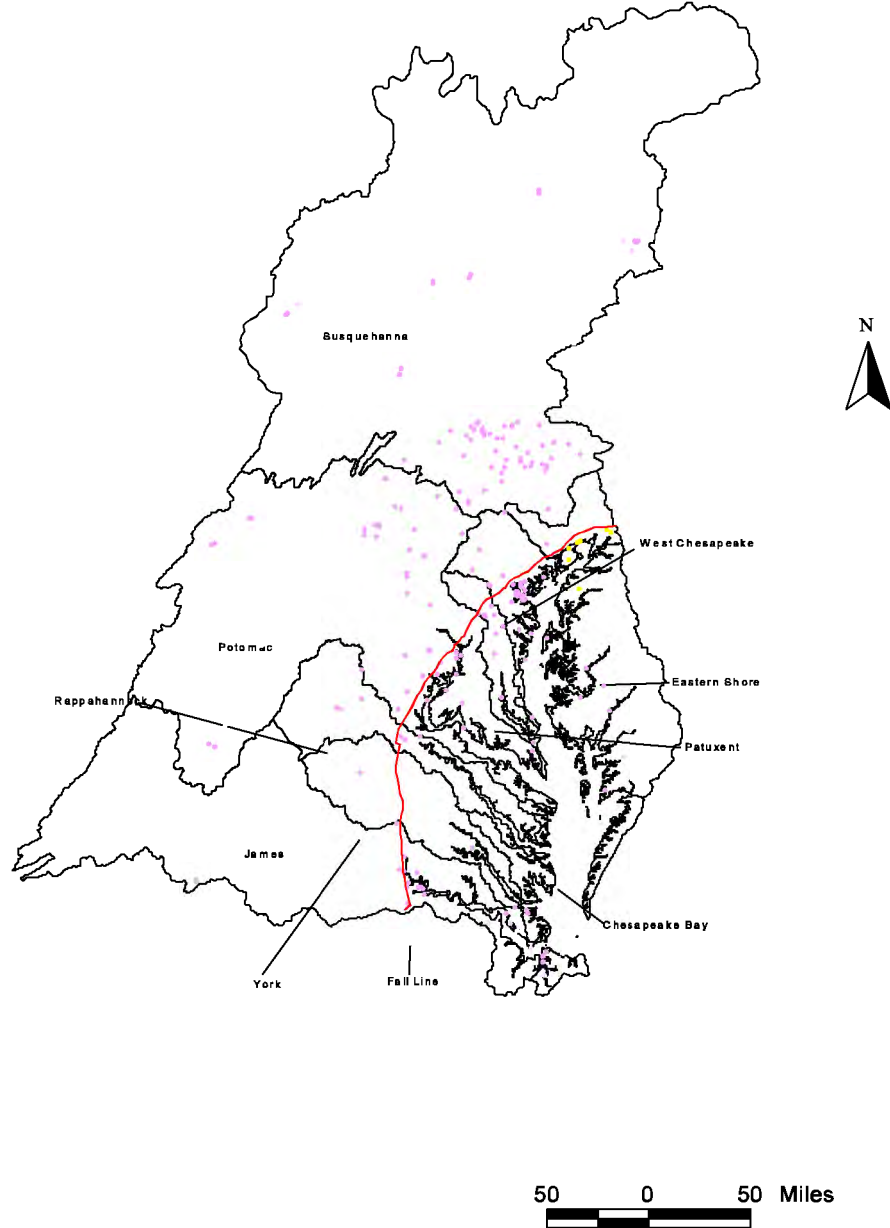


Figure 1.1. Chesapeake Bay Basin major point source dischargers.

## **CHEMICALS REPORTED**

Between all the above data sources, there are over 800 chemicals reported, the majority of which are reported through the VA TMP. To calculate loadings for 800 chemicals would have been too immense of an undertaking in the time allowed for this report. Therefore, it was decided to include only a subset of these chemicals in this report. The 231 chemicals chosen include all of the potentially toxic chemical parameters in PCS, the priority pollutants, the Toxics of Concern list chemicals, and the Chemicals of Potential Concern. Appendix C includes a complete list of loadings for all facilities and all 231 chemicals. Appendix A lists the 231 parameters for which data were available to calculate loadings. Due to the large amount of data, Tables 1.2 - 1.4 provide a summary for only a subset of the 231 parameters. This chemical subset of 79 parameters includes the 1990 list of Toxics of Concern (as well as the draft revised 1996 list of the Toxics of Concern), the 1990 list of Chemicals of Potential Concern, and individual PCB's and PAH's. Because some facilities did not report any of the chemical subset, only 228 facilities were used for the loading analysis.

This report also summarizes data in terms of the chemical categories of metals, PCBs, pesticides, PAHs, organics, and inorganics. Metals are substances or mixtures such as lead, copper, or mercury. PCBs (Polychlorinated biphenyls), although banned, are used as fire retardants and can be found in electric transformers and other machinery. Pesticides are compounds, either organic or inorganic which are used to control the growth of plants (herbicides), insects (insecticides), or fungus (fungicides). PAHs (Polycyclic Aromatic Hydrocarbons) are compounds such as naphthalene, or phenanthrene, which come from the combustion of fossil fuels and from oil and grease. Organic chemicals include compounds containing hydrocarbons and their derivatives (hydrocarbon combined with other elements, principally nitrogen and oxygen). Organics discussed in this report include all organic chemicals except PCBs, PAHs and pesticides. Inorganic chemicals include compounds other than organic chemicals and metals.

## **MAPPING OF POINT SOURCE FACILITIES**

In coordination with the calculation of loads for facilities, an effort was made to accurately map all of the major point sources. Location information (latitude/longitude, address, county, zip codes) from PCS was compiled for all major facilities. The information was used to map each facility in ArcView in the following ways: If a facility had an accurate latitude/longitude it was used first. If a correct lat/long was unattainable, the facility was mapped using address matching. If neither an accurate lat/long or address was available, the facility was mapped using zip code centroid matching. Figure 1.1 shows the accurate location of all major point source dischargers in the Chesapeake Bay watershed.

## **METHODOLOGY**

There are over 4000 point source dischargers in the Chesapeake Bay Watershed. The majority of these facilities are minor facilities, and depending upon the state, data for them are generally not reported in PCS unless they are minors deemed “significant”. Calculating loads for all the watershed facilities was too large of an undertaking for this report. In order to maintain consistency between all the jurisdictions, only major facilities are included in the loadings analysis.

Monthly flows were matched with monthly concentration values and the load calculated according to the formula below. Monthly loads for each individual year were averaged to obtain an annual load.

The following formula was used to estimate the annual average load of chemical contaminants for all states:

Annual Load (lbs/yr) = Concentration x Flow x 8.344 x # of days in the year for which data was available

where:

Load = pounds /year (lbs/yr)

Concentration = milligrams/liter (mg/L)

Flow = million gallons/day (MGD)

8.344 = a factor for converting MGD and mg/L into lbs/day

Outfalls within each facility were identified, when possible, as effluent, influent, internal, etc. All outfalls identified as effluent were summed, by year, to obtain an annual load for the facility. The annual loads for each year for each facility were averaged to obtain the load estimates as reported in this chapter.

In cases where a concentration was present but the corresponding flow was not and vice versa, a zero was assumed and put in place of the missing value. Due to this method, some of the loading estimates may be recorded as a zero. A zero may also indicate the chemical was non-detect, or that the concentration value was not recorded in the PCS database.

For each year at any given facility, the average concentration for any given chemical was used in the loads calculation regardless of how many data points were present for each year. If there were no data points for a given year, the average did not include that year. For example, if a copper load was only obtainable for a given facility for the years of 1992, 1994, 1995, and 1996, the average would be the sum of the loads for those years, divided by the four years for which there was data available.

*District of Columbia*

Blue Plains WWTP was the only facility in DC for which data was obtainable. There are 3 additional active major facilities in D.C. for which data was unavailable in PCS.

Data collected from PCS was supplemented by data from Monthly Operation Reports where there were missing parameters or monthly values from PCS. Using monthly average concentration and flow values, annual average concentrations and flows were calculated. For some pollutants only a single data value was available to estimate the average concentration.

*Maryland*

Data collected from PCS was supplemented by data from permit applications where there were missing parameters or monthly values from PCS. If DMR (PCS) data existed for a particular chemical, these data alone were used to calculate loads. If only permit application data existed for a particular chemical, these data along with PCS flows were used to calculate loads. For some pollutants at some facilities, however, only a single data value was available to estimate the average concentration. Using monthly average concentration and monthly average flow values, annual average concentrations and flows were calculated.

*Virginia*

Data collected from PCS was supplemented by data from permit applications and data from the VA TMP program where there were missing parameters or monthly values from PCS. If DMR (PCS) data existed for a particular chemical, these data alone were used to calculate loads. If only TMP data exist for a particular chemical, these data along with PCS flows were used to calculate loads. If only permit application data exist for a particular chemical, these data along with PCS flows were used to calculate loads. For some pollutants at some facilities, however, only a single data value was available to estimate the average concentration. Using monthly average concentration and monthly average flow values, annual average concentrations and flows were calculated.

*Pennsylvania*

Data collected from PCS was the only data source used in the calculation of annual loads. Annual loads were calculated using monthly average concentration and monthly average flow data from the PCS database. For some pollutants at some facilities, however, only a single data value was available to estimate the average concentration.

## UNCERTAINTY AND DATA HANDLING

### *Coverage*

The non-electronic data for this chapter was collected over a period of 14 months beginning in July of 1996 through September of 1997. Data collected in the beginning may not have the same temporal coverage as the data collected towards the end of the data collection process. For instance, data collected in July of 1996 will not have a complete year of data for 1996. PCS data was retrieved from 1992 through September of 1996.

The point source loading estimates to the Chesapeake Bay are underestimated due to the inclusion of only major dischargers within the signatory states/Districts (Maryland, Virginia, Pennsylvania, and the District of Columbia). The loadings of minor dischargers collectively may be significant. It was decided to maintain consistency between all states in choosing only major dischargers, and as time allows in future efforts, to assimilate data for minor facilities as well.

### *Non-detects of various chemicals*

The definition of the Detection Limit (DL) is the lowest value to which a compound can be reliably measured as being present. A Quantitation Limit (QL) is the level at which the quantity or concentration of a pollutant can be reliably determined. Detection Limits and Quantitation Limits for any given chemical vary depending upon the analytical method and/or the laboratory conducting the analysis. It is often uncertain as to whether a detection limit, or a quantitation limit was reported. Approximately 80% of the data collected for this chapter was non-detect. The method in which non-detect (ND) concentrations are treated can result in very different loading estimates. Non-detect concentrations can be set equal to zero, to the detection limit, or some value in between (such as half the detection limit), with each option resulting in a different loading estimate.

For these loading estimates, the loadings are presented in a range, setting all ND to both zero and the DL. In cases where a chemical was reported as ND, but was missing a DL, a default detection limit value was used. Default values were obtained from EPA's Environmental Monitoring Methods Index (EMMI). The EMMI database contains an inventory of information on environmentally significant analyses monitored by the US EPA and methods for their analyses. The detection limit with the most appropriate method was chosen for each chemical missing a detection limit. The list of EMMI default detection limits can be found in Appendix B, along with the complete chemical list.

All tables in this chapter present the loading estimates by a range. The low estimate of loadings represents the average of both non-detects (set to zero) and detected values. The high estimate of loadings represents the average of non-detects (set to the detection limit) and detected values. It is important to note that for certain chemicals (all PCB's, pesticides, and most PAH's),

virtually all values were non-detect, therefore, the detection limits are driving the high range of the loads.

The estimated load may vary significantly depending upon whether the non-detects used to calculate the loadings are set to zero or the detection limit. As an example, Figure 1.2 represents the relative loadings of point source chemical categories with the non-detects of point sources set equal to zero. With this treatment of the non-detects, metals are the predominant chemical load with PCBs, PAHs and pesticides virtually zero. Figure 1.3 represents the relative loadings of all chemical categories with the non-detects set equal to the detection limit. Using this treatment of non-detects, the relative loads of PCBs and pesticides dominate all other chemical categories.

The chapter entitled “Relative Importance of Point and Non-Point Sources of Chemical Contaminants to the Chesapeake Bay” uses the average of the low and high loading estimates for point sources. This chapter further discusses the uncertainty in dealing with data containing many non-detects.

### *PCS Reporting*

Data in PCS is entered into the database in many different ways. There are many fields for which chemical and flow data can be entered: average load, maximum load, concentration minimum, concentration average, and concentration maximum. Concentration average was the preferred value, however, in cases where this was missing, concentration maximum or minimum was assumed to represent the average. Records for which concentration maximum or minimum were used were documented in the comments field in the database. In cases where average load or maximum load existed, and a concentration value was lacking, the flow and the load were used to back calculate to the concentration. The back calculated concentrations were then used in the loading calculations as were all other concentrations. Records for which a back calculated concentration was generated were documented in the comments field in the database.

Data was also inconsistently reported between each jurisdiction. Each state has different methods and requisites of entering data into PCS. These differences proved challenging when the data for all states was compiled into a database. Consistency between all states had to be restored before the data could be used to produce loadings.

### *Metals Reporting in a Variety of Forms*

Several metals were reported in a variety of forms (such as copper appearing as total copper, dissolved copper and total recoverable copper). For presentation and summary purposes, wherever multiple forms of a particular chemical were reported, they were consolidated into one parameter to produce Table 1.2. A hierarchy was implemented when consolidating such chemical parameter which was to use the highest value whenever more than one form per facility

## *Point Source Loadings*

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was reported.

### *Nitrogen Reporting*

A similar situation exists regarding reporting of nitrogen and nitrogen species as for metals discussed above. Nitrogen and nitrogen species are reported in various ways in the point source database including ammonia plus unionized ammonia, ammonia nitrogen, nitrate nitrogen, nitrate dissolved nitrogen, and nitrite plus nitrate. The inventory has combined these data where appropriate in an effort to determine one representative load of a certain species. For example, ammonia plus unionized ammonia and nitrogen ammonia total are combined to present one load for ammonia nitrogen. In cases where a facility supplied data for both parameters, the highest value only was used. Nitrogen nitrate dissolved and nitrogen nitrate total are combined into nitrate nitrogen. Nitrite plus nitrate is listed as nitrite and nitrate nitrogen.

### *Outfalls*

Outfalls are often not identified clearly in PCS. It was difficult to distinguish effluent, influent, stormwater, and internal outfalls within the PCS database. Best efforts were made to verify effluent outfalls with each state before including them in the loadings calculations, however, some outfalls may have been double counted or missed.

### *Influent concentrations/Cooling water discharges*

Influent concentration values are often present for larger facilities such as power plants, which use stream water for cooling purposes. Due to the complexity of the data, influent data were not used unless specifically available to calculate the “net effluent” chemical concentrations. Loads for those facilities may be overestimated due to the fact that influent loadings were not taken into account.

### *Stormwater Outfalls*

There are many facilities which have stormwater related outfalls. The discharge of these outfalls is dependent upon rainfall, hence they do not discharge 365 days/year. Every attempt was made to accurately identify and discount these outfalls, however, some may have missed. In these cases, the loadings may be overestimated.

### *Unit inconsistencies*

Units are not consistently reported in PCS. In addition, units for any given parameter may be inconsistently and inaccurately reported in the PCS database. For instance, flow values may have been reported in MGD, gallons per day, or thousand gallons per day, depending upon the facility, outfall, and/or who entered the data into PCS. It was often difficult to ascertain the

correct units in questionable cases. Questionable flows and concentrations were sent to each state and the District of Columbia for review and correction.

#### *Data Review*

The Chesapeake Bay Program requested review of data for 25 facilities where questions arose in the database. Responses from 22 facilities were received which allowed corrections to be made in the inventory regarding flow quantities, unit errors or typos, and concentrations.

#### *Off-Line Facilities*

Some facilities in the inventory stopped discharging during the years of 1992-1996. Only the years of actual discharge were used for load calculations for facilities which ceased discharging during the period of data collection.

### **DISCUSSION**

Table 1.2 presents the total Chesapeake Bay basin point source load estimates for a subset of the 79 chemical parameters analyzed for the purposes of this chapter. Note that only 51 chemicals are included in Table 1.2. This is because, as explained earlier in this report, where related chemicals were reported in a variety of parameters, they were consolidated to one parameter for summary purposes in Table 1.2.

The top 18 chemicals with the highest loads are presented below in descending order. These are the chemicals whose low load estimates are greater than 1000 lbs/yr.



### *Point Source Loadings*

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#### **Top 18 Chemicals with the highest loads**

<b>CHEMICAL</b>	<b>Loads* (lbs/year)</b>
AMMONIA NITROGEN	212,027,519.36
NITRATE NITROGEN	17,150,864.30
NITRITE + NITRATE NITROGEN	5,706,187.43
IRON	1,932,958.60
ALUMINUM	662,631.32
ZINC	563,786.40
MANGANESE	531,045.18
PETROLEUM HYDROCARBONS	367,803.65
COPPER	114,224.75
NICKEL	42,435.87
CHROMIUM	20,972.61
LEAD	19,221.61
CADMIUM	9,997.50
NAPHTHALENE	8,543.91
ARSENIC	3,165.52
CHLORPYRIFOS	2,878.05
MERCURY	1,390.99
2,4-DINITROPHENOL	1,254.00

This list includes chemicals with low load estimates higher than 1000 lbs/year.

\* Based on low estimates.

Tables 1.3a-p present the point source load estimates and percent total by major basin. Tables 1.3 and 1.4 include all 79 chemical parameters in their unconsolidated forms.

Table 1.4 presents point source load estimates by individual states. Note that for the 80 facilities in Pennsylvania, data are unavailable for many parameters. This is due to the sources of data (see Table 1.1), which for Pennsylvania, is much less voluminous than for the other jurisdictions. Thus, it's not necessarily true that loads are less in Pennsylvania, but that less data is available.

Appendix B presents the loadings for chemical categories by industry type or standard industrial code (SIC code) for 227 out of the 228 facilities for which loads were calculated for the 79 chemical parameters subset. There is one facility for which the SIC code was unavailable. Out of the 227 facilities, the majority (134) are classified as sewerage, and 20 provide electrical services. The chemical categories summarized in Appendix B are Inorganics, Metals, Organics, PAHs, PCBs, and Pesticides. Based on the low load estimates, the loads of pesticides are only coming from sewerage. PCBs were only recorded for a General Medical/Surgical Hospital

facility. The highest loads of PAHs are from sewerage, plastic materials/synthesized resins, and paper mills. The highest loads of organics are from electrical services, sewerage, and ammunition. Industrial classes of sewerage, inorganic pigments, and medical chemicals represent the highest loads of metals, and classes of nitrogen fertilizers, sewerage and paper mills represent the highest loads of inorganics. Based on the high load estimates, the highest loads of pesticides, PCBs, PAHs, and organics are coming from electrical services, plastic materials, and synthesized resins. The highest loads of metals are coming from the same industrial class for metals' low load estimates, which are sewerage, inorganic pigments, and medical chemicals. The same situation applied to inorganics, its high load and low load estimates have the same source for highest loading, which are nitrogen fertilizers, sewerage and paper mills.

Figures 1.2 and 1.3 show the relative total low and high Chesapeake Bay Basin point source loads by chemical category. Note that the inorganic category is not included in these figures. This is because approximately 98% of the point source load is from inorganics, primarily nitrogen compounds. And as mentioned previously the amount of pesticides and organics are driven by their detection limits, as seen in Figure 1.3 as compared to Figure 1.2.

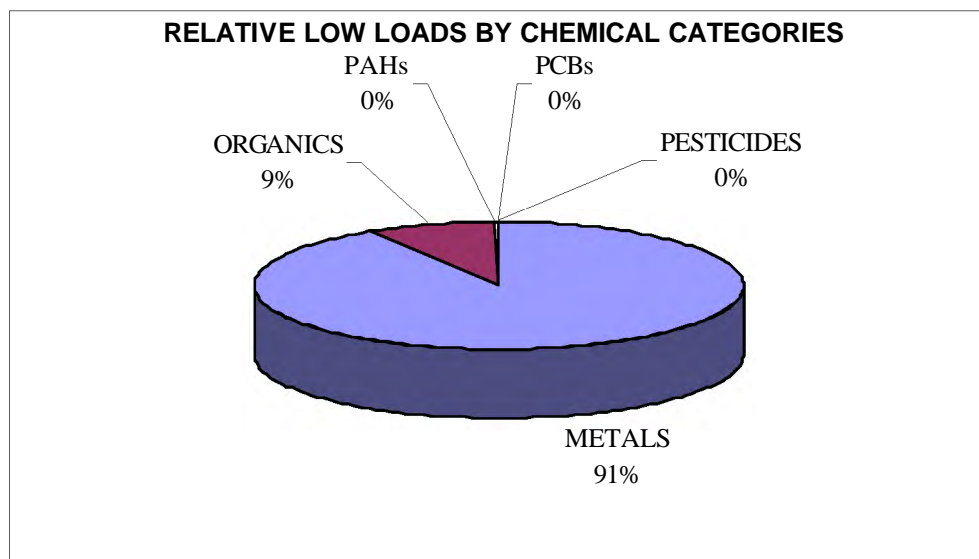


Figure 1.2. Relative Low Chesapeake Bay Basin point source loads by chemical category.

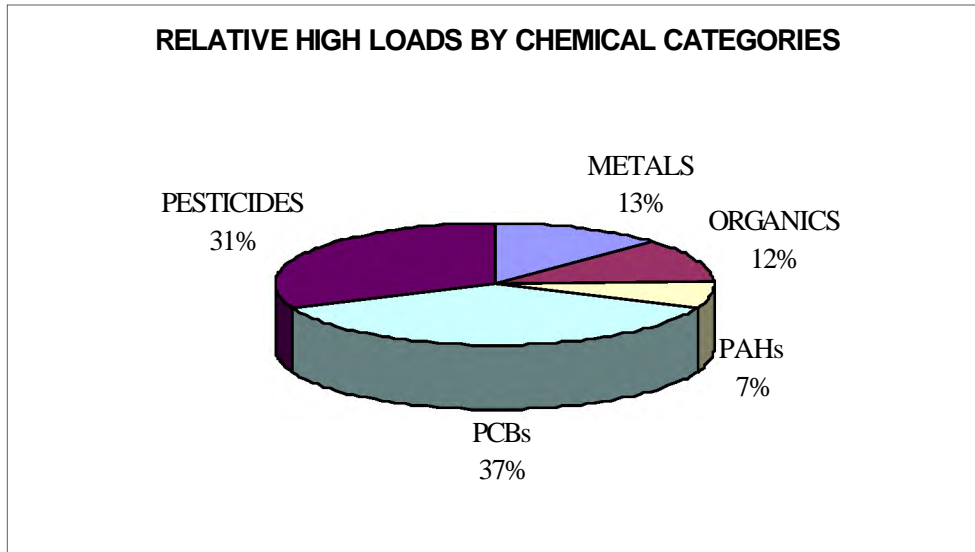


Figure 1.3. Relative High Chesapeake Bay Basin point source loads by chemical category.

Figures 1.4 - 1.9 show the low and high loading estimates of each individual chemical category by the major basins (Note that Figure 1.8, loading estimates for Inorganics, is primarily driven by the nitrogen compounds). Data from Table 1.2, using consolidated methods and nitrogen species parameters, were used to produce these graphs. Graphs not showing a low estimate indicate that the majority of the values were non-detect. As shown in Figures 1.5 - 1.7, the high loadings for PCB's, pesticides, and PAH's are driven primarily by the detection limit. The low estimates for these chemical categories are mostly zero, indicating that nearly all the concentrations were non-detect. Graphs which show a large low estimate and a small high estimate indicate that most of the concentrations were detected. The highest loadings of metals are in the Potomac, and are due primarily to iron, aluminum, manganese, zinc, and copper. Highest loadings of Inorganics are in the James which is primarily due to nitrogen species.

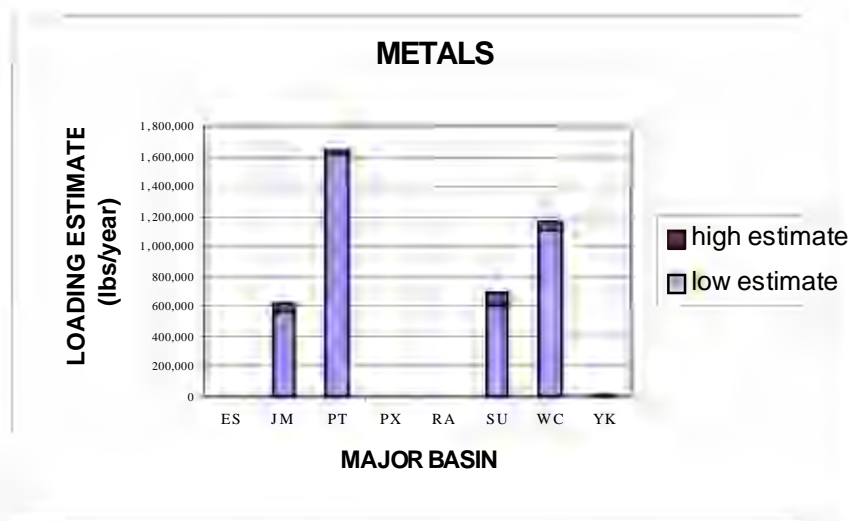


Figure 1.4. Loading estimates of metals by major basin.

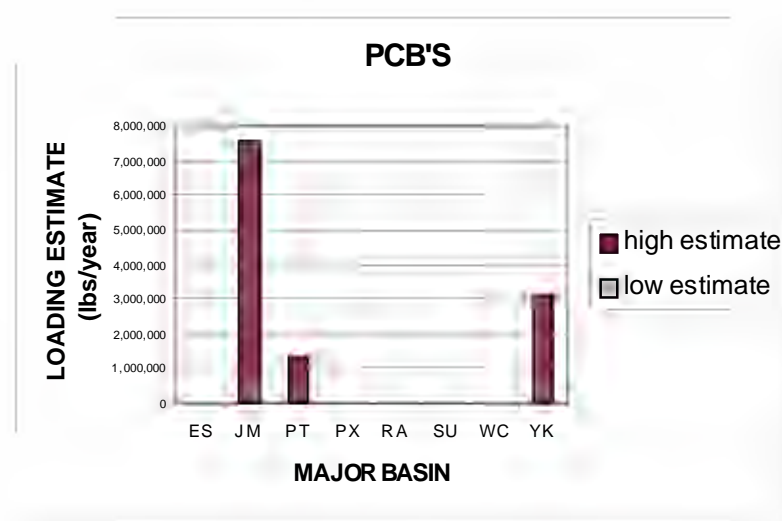


Figure 1.5. Loading estimates of PCB's by major basin.

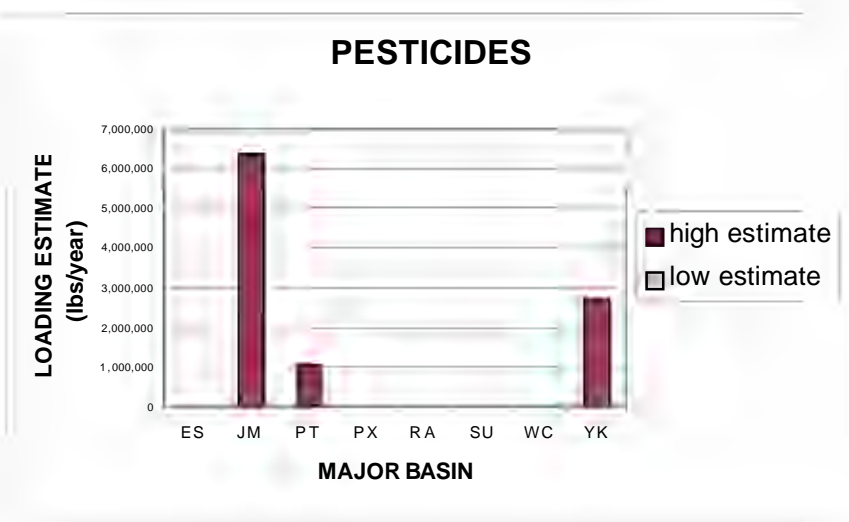


Figure 1.6. Loading estimates of pesticides by major basin.

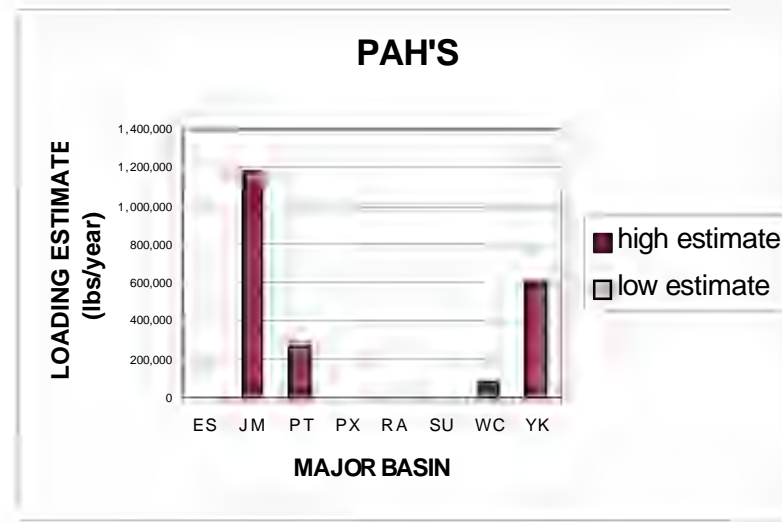


Figure 1.7. Loading estimates of PAH's by major basin.

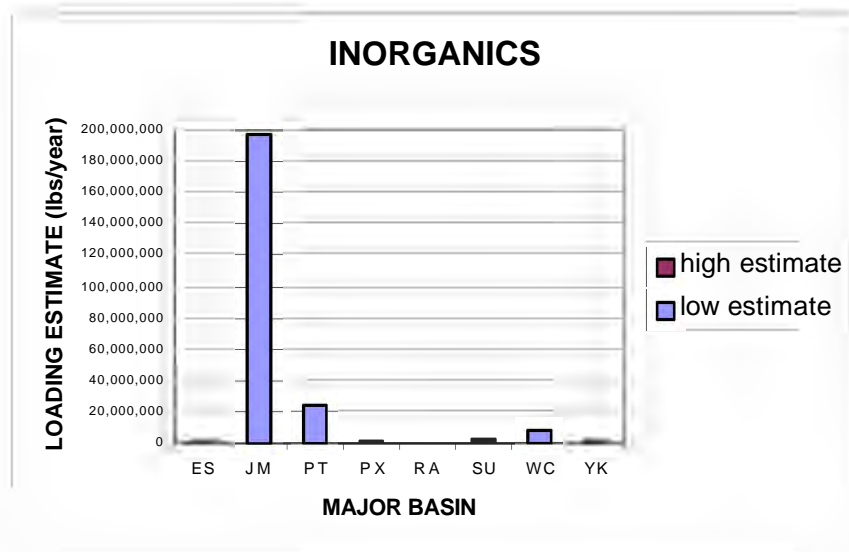


Figure 1.8. Loading estimates of inorganics by major basin.

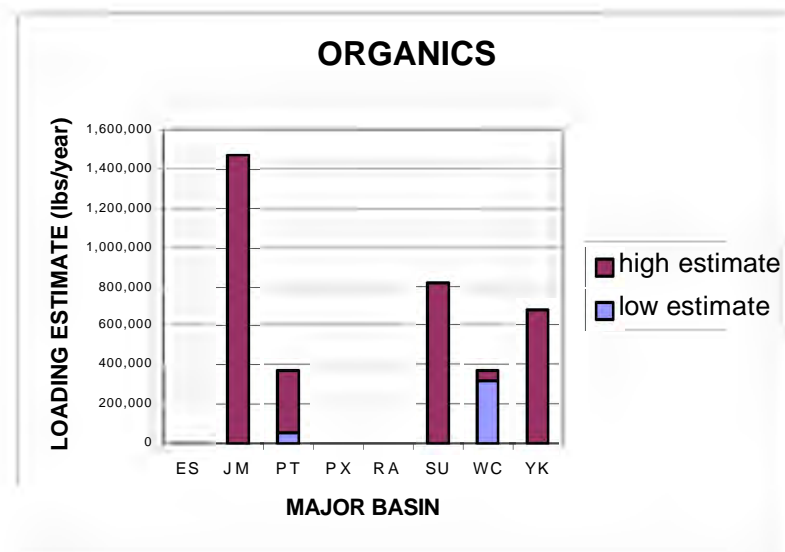


Figure 1.9. Loading estimates of organics by major basin.

ES = Eastern Shore  
 JM = James  
 PT = Potomac  
 PX = Patuxent  
 RA = Rappahannock  
 SU = Susquehanna  
 WC = West Chesapeake  
 YK = York

## **CORRELATION WITH 1994 TOXICS LOADING AND RELEASE INVENTORY**

The results in this chapter cannot be directly compared to the results in the Point Source chapter of the 1994 TLRI. The time period of data collected for the last report varied depending upon state. Facilities included in the 1994 TLRI comprised about one third of the majors. Additionally, the sources of data are more comprehensive in this analysis than in the previous TLRI. For these reasons, the loadings in this new chapter may appear greater when compared to the last report.

This version of the Point Source chapter of the TLRI provides more comprehensive and up-to-date loading estimates when compared to the 1994 report. This inventory includes nearly twice as many facilities, additional and different data sources collected over a consistent time period, and reports loadings on more chemicals. Careful consideration needs to be taken with regards to the limitations, assumptions, and caveats of the data presented in this chapter when comparing any of the results from this inventory with the results of the 1994 inventory.

## **RECOMMENDATIONS**

- ▶ Further efforts should be made to include additional D.C. facilities, especially majors. Insufficient data exists for the 3 remaining D.C. majors: Washington Aquaduct-Delecarlia Plant, Pepco-Potomac Electric Company, and Potomac Electric Power Company.
- ▶ EPA's PCS system should be improved and be made useful for the purpose of calculating loadings for point source dischargers.
- ▶ Special training and discussion seminars should be held for all personnel from the Bay jurisdictions who are responsible for PCS entry. A standard approach for entering data should be firmly established.
- ▶ Incorporate a new application requirement that a pre-existing facility must report average annual loadings for all pollutants identified in their application and also for those listed on their previous permit. This submission should be maintained in an appropriate database.
- ▶ Incorporate a standard permit requirement that facilities submit an annual summary of total loads during that year using a combination of actual DMR data and estimates based on their previous permit application data. Maintain these annual loadings in an appropriate database.
- ▶ The following inaccuracies and inconsistencies within PCS need to be amended:
  - Units for all parameters need to be consistently and accurately reported in the PCS database.
  - Duplicate parameter codes in PCS need to be eliminated. The use of CAS

## *Point Source Loadings*

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- numbers as a unique chemical identifier should be implemented.
  - Records of missing data without an explanation code should either be filled in with data, or explained with a code in the database.
  - Data for metals should be properly recorded as total, total recoverable, or dissolved in PCS.
  - Numeric data should be stored in fields with numeric formatting. Any qualifying text should be placed in a separate field from numeric data.
- 
- ▶ A consistent criteria for including priority minor dischargers in future inventory updates should be developed.
  - ▶ States should clearly identify outfalls for facilities with intake pipes, and/or non-contact cooling water from the same water body. The net effluent load should be determined using the influent loads.
  - ▶ To better estimate the loads of chemicals with non-detects, such as PCB's, further analyses must be conducted to assess typical pollutant concentrations in point source discharges. The recent published report entitled the "Study of the Loading of PCB's from Tributaries and Point Sources Discharging to the Tidal Delaware River," put out by the Delaware River Basin Commission, contains data that may provide better estimates of PCB loads for those facilities with non-detects.
  - ▶ The mapping effort verified the location of all major dischargers in the Chesapeake Bay watershed. This list of facilities, along with any related location information should be updated in the PCS database.
  - ▶ Involve dischargers in the review of the data for future loading inventories.
  - ▶ A discharger outreach program should be established focusing on new uses of DMR data as well as education on completing DMR's properly. In addition, the importance of correct flow values and units should be emphasized.
  - ▶ A zero present in the loading estimates can have several meanings. It may indicate the chemical was non-detect, or that flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration was not recorded in the PCS database. A procedure for distinguishing between each of the above cases should be established for future inventory and database updates.
  - ▶ Any point source data not reported in PCS should be submitted to the Chesapeake Bay Program in accordance to the data submittal requirements of the Information Management System.
  - ▶ Data for point sources within the Chesapeake Bay Watershed in non-signatory states

(West Virginia, Delaware, and New York) should be included in future inventory updates.

- ▶ Additional analyses of intake cooling waters should be performed to determine net discharge loads where not done previously.
- ▶ Loads for the approximate 3700 minors should be investigated.
- ▶ Indirect discharges to the POTW's should be investigated.
- ▶ Consider including other chemicals than the list of 79 that were included in this chapter's analysis.



## Point Source Loadings

Table 1.2. Total Chesapeake Bay Watershed Load Estimates by Chemical.

CHEMICAL	TOTAL CHESAPEAKE BAY WATERSHED LOAD ESTIMATE (lbs/year)	
	LOW	HIGH
2,4,6-TRICHLOROPHENOL	231.87	200,451.21
2,4-DICHLOROPHENOL	32.24	223,189.26
2,4-DIMETHYLPHENOL	221.71	209,598.20
2,4-DINITROPHENOL	1,254.00	2,375,251.21
2-METHYL-4-CHLOROPHENOL	0.00	316,221.58
2-METHYLNAPHTHHALENE	0.00	928.84
ACENAPHTHENE	1.92	74,103.75
ALDRIN	540.41	92,405.67
ALUMINUM	662,631.32	672,864.16
AMMONIA NITROGEN	212,027,519.36	212,115,969.45
ARSENIC	3,165.52	12,061.04
BENZO[A]ANTHRACENE	54.92	626,162.00
BENZO[A]PYRENE	54.73	115,160.68
BENZO[GHI]PERYLENE	3.84	167,453.58
CADMIUM	9,997.50	14,220.73
CHLORDANE	0.00	392,854.86
CHLORPYRIFOS	2,878.05	3,024.96
CHROMIUM	20,972.61	126,599.92
CHRYSENE	185.62	115,212.50
COPPER	114,224.75	122,642.80
DIBENZO(A,H)ANTHRACENE	3.84	121,761.66
DIELDRIN	0.10	178,967.89
DIOXIN	0.07	4,203.26
ENDOSULFAN - ALPHA	0.00	2,274,682.66
ENDOSULFAN - BETA	0.00	2,803,653.33
ENDRIN ALDEHYDE	0.00	2,410,241.49
FLUORANTHENE	55.88	103,693.64
FLUORENE	42.86	103,566.19
INDENO(1,2,3-CD)PYRENE	3.84	165,240.85
IRON	1,932,958.60	1,933,405.83
LEAD	19,221.61	61,741.28
MANGANESE	531,045.18	532,168.84
MERCURY	1,390.99	7,103.98
NAPHTHALENE	8,543.91	170,764.04
NICKEL	42,435.87	77,609.57
NITRATE NITROGEN	17,150,864.30	17,168,223.99
NITRITE + NITRATE NITROGEN	5,706,187.43	5,718,090.97
PCB 1221	0.00	1,173,074.17
PCB 1232	0.00	1,904,299.62
PCB 1242	0.00	1,904,268.49
PCB 1254	0.00	1,393,319.56
PCB-1016	0.00	1,904,225.58
PCB-1248	0.00	1,904,030.00

***Point Source Loadings***

<b>CHEMICAL</b>	<b>LOW</b>	<b>HIGH</b>
PCB-1260	0.15	1,904,119.68
PENTACHLOROBIPHENYL	0.00	97.73
PETROLEUM HYDROCARBONS	367,803.65	395,822.06
PHENANTHRENE	76.94	216,302.01
POLYCHLORINATED BIPHENYLS (PCBS)	0.00	15,481.95
PYRENE	84.51	162,085.78
TOXAPHENE	0.00	2,008,422.57
ZINC	563,786.40	568,580.05

Table 1.3a. Estern Shore Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Eastern Shore)		EASTERN SHORE BFL		
			10		10
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL					
2,4-DICHLOROPHENOL					
2,4-DIMETHYLPHENOL					
2,4-DINITROPHENOL					
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPHTHALENE					
ACENAPHTHENE					
ALDRIN					
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL					
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA			56,562.75	0.79	56,562.75
ARSENIC, DISSOLVED					
ARSENIC, TOTAL					
ARSENIC, TOTAL RECOVERABLE					
BENZO[A]ANTHRACENE					
BENZO[A]PYRENE					
BENZO[GHI]PERYLENE					
CADMIUM, DISSOLVED					
CADMIUM, TOTAL					
CADMIUM, TOTAL RECOVERABLE					
CHLORDANE					
CHLORPYRIFOS					
CHROMIUM, DISSOLVED					
CHROMIUM, HEXAVALENT					
CHROMIUM, HEXAVALENT DISSOLVED					
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL					
CHROMIUM, TOTAL RECOVERABLE					
CHROMIUM, TRIVALENT					

Table 1.3a. Estern Shore Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Eastern Shore)		EASTERN SHORE BFL		
			10		10
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
CHRYSENE					
COPPER, DISSOLVED					
COPPER, TOTAL			328.05	0.35	328.05
COPPER, TOTAL RECOVERABLE					
DIBENZO(A,H)ANTHRACENE					
DIELDRIN					
DIOXIN					
ENDOSULFAN - ALPHA					
ENDOSULFAN - BETA					
ENDRIN ALDEHYDE					
FLUORANTHENE					
FLUORENE					
INDENO(1,2,3-CD)PYRENE					
IRON, DISSOLVED					
IRON, TOTAL					
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED					
LEAD, TOTAL					
LEAD, TOTAL RECOVERABLE					
MANGANESE, DISSOLVED					
MANGANESE, TOTAL					
MERCURY, DISSOLVED					
MERCURY, TOTAL					
MERCURY, TOTAL RECOVERABLE					
NAPHTHALENE					
NICKEL, DISSOLVED					
NICKEL, TOTAL			1.52	4.67E-03	1.52
NICKEL, TOTAL RECOVERABLE					
NITRITE PLUS NITRATE			259,201.34	4.54	259,201.34
NITROGEN, AMMONIA TOTAL			1,545,791.42	0.74	1,545,791.42
NITROGEN, NITRATE DISSOLVED					

Table 1.3a. Estern Shore Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Eastern Shore)		EASTERN SHORE BFL		
			10		10
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
NITROGEN, NITRATE TOTAL			45,420.71	0.27	45,420.71
PCB 1221					
PCB 1232					
PCB 1242					
PCB 1254					
PCB-1016					
PCB-1248					
PCB-1260					
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS			1,301.59	0.35	1,301.59
PHENANTHRENE					
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE					
TOXAPHENE					
ZINC, DISSOLVED					
ZINC, TOTAL			24.13	4.81E-03	24.13
ZINC, TOTAL RECOVERABLE					

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3b. James River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	JAMES RIVER AFL		JAMES RIVER BFL		
	16		19		35
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL	226.39	97.64	0.00	0.00	226.39
2,4-DICHLOROPHENOL	30.05	93.20	0.00	0.00	30.05
2,4-DIMETHYLPHENOL	210.96	95.15	0.00	0.00	210.96
2,4-DINITROPHENOL	0.00	0.00	1,245.77	99.34	1,245.77
2-METHYL-4-CHLOROPHENOL	0.00	0.00	0.00	0.00	0.00
2-METHYLNAPHTHALENE			0.00	0.00	0.00
ACENAPHTHENE	0.00	0.00	0.00	0.00	0.00
ALDRIN	0.00	0.00	0.00	0.00	0.00
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL	95,551.75	16.42			95,551.75
ALUMINUM, TOTAL RECOVERABLE			1,242.59	1.79	1,242.59
AMMONIA+UNIONIZED AMMONIA	0.00	0.00	3,321,361.22	46.32	3,321,361.22
ARSENIC, DISSOLVED	0.00	0.00	0.00	0.00	0.00
ARSENIC, TOTAL	491.19	17.31	0.00	0.00	491.19
ARSENIC, TOTAL RECOVERABLE	0.00	0.00	59.91	18.25	59.91
BENZO[A]ANTHRACENE	0.00	0.00	52.73	96.01	52.73
BENZO[A]PYRENE	0.00	0.00	44.43	81.17	44.43
BENZO[GH]PERYLENE	0.00	0.00	0.00	0.00	0.00
CADMIUM, DISSOLVED	21.74	2.11	672.29	65.25	694.03
CADMIUM, TOTAL	125.20	1.60	602.46	7.70	727.67
CADMIUM, TOTAL RECOVERABLE	19.54	1.27	1,460.87	95.01	1,480.42
CHLORDANE	0.00	0.00	0.00	0.00	0.00
CHLORPYRIFOS			0.00	0.00	0.00
CHROMIUM, DISSOLVED	464.30	21.25	370.89	16.98	835.19
CHROMIUM, HEXAVALENT	42.10	6.12	208.95	30.36	251.05
CHROMIUM, HEXAVALENT DISSOLVED	929.31	71.56	280.36	21.59	1,209.67
CHROMIUM, HEXAVALENT TOTAL	12.83	100.00	0.00	0.00	12.83
CHROMIUM, TOTAL	732.58	4.40	2,762.79	16.59	3,495.37
CHROMIUM, TOTAL RECOVERABLE	929.75	55.98	261.68	15.75	1,191.43
CHROMIUM, TRIVALENT					
CHRYSENE	0.00	0.00	42.90	23.11	42.90
COPPER, DISSOLVED	3,435.67	63.27	1,550.29	28.55	4,985.96
COPPER, TOTAL	851.76	0.92	11,201.74	12.06	12,053.50
COPPER, TOTAL RECOVERABLE	1,481.07	7.29	7,628.09	37.55	9,109.15
DIBENZO(A,H)ANTHRACENE	0.00	0.00	0.00	0.00	0.00
DIELDRIN	0.00	0.00	0.00	0.00	0.00
DIOXIN	0.00	0.00	0.00	0.00	0.00

Table 1.3b. James River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	JAMES RIVER AFL		JAMES RIVER BFL		
	16		19		35
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)    LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)    LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ENDOSULFAN - ALPHA	0.00	0.00	0.00	0.00	0.00
ENDOSULFAN - BETA	0.00	0.00	0.00	0.00	0.00
ENDRIN ALDEHYDE	0.00	0.00	0.00	0.00	0.00
FLUORANTHENE	12.18	21.80	41.78	74.77	53.96
FLUORENE	0.00	0.00	40.66	94.88	40.66
INDENO(1,2,3-CD)PYRENE	0.00	0.00	0.00	0.00	0.00
IRON, DISSOLVED					
IRON, TOTAL	47,521.92	2.46	329.03	0.02	47,850.94
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED	557.63	52.25	221.30	20.74	778.93
LEAD, TOTAL	757.40	4.69	4,487.67	27.79	5,245.07
LEAD, TOTAL RECOVERABLE	282.31	9.89	1,873.42	65.61	2,155.73
MANGANESE, DISSOLVED					
MANGANESE, TOTAL	41,440.93	8.94	236,573.89	51.03	278,014.82
MERCURY, DISSOLVED	451.63	93.48	10.58	2.19	462.21
MERCURY, TOTAL	8.98	1.31	24.40	3.57	33.39
MERCURY, TOTAL RECOVERABLE	4.68	1.99	221.84	94.56	226.51
NAPHTHALENE	0.00	0.00	39.55	0.46	39.55
NICKEL, DISSOLVED	1,127.28	9.29	6,580.59	54.24	7,707.87
NICKEL, TOTAL	5,582.46	17.12	6,218.59	19.08	11,801.04
NICKEL, TOTAL RECOVERABLE	482.61	20.92	613.80	26.61	1,096.40
NITRITE PLUS NITRATE	100,926.75	1.77	58,006.91	1.02	158,933.66
NITROGEN, AMMONIA TOTAL	30,636,158.06	14.61	163,398,337.46	77.92	194,034,495.51
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL	191,905.02	1.13	959,786.65	5.65	1,151,691.67
PCB 1221	0.00	0.00	0.00	0.00	0.00
PCB 1232	0.00	0.00	0.00	0.00	0.00
PCB 1242	0.00	0.00	0.00	0.00	0.00
PCB 1254	0.00	0.00	0.00	0.00	0.00
PCB-1016	0.00	0.00	0.00	0.00	0.00
PCB-1248	0.00	0.00	0.00	0.00	0.00
PCB-1260	0.00	0.00	0.00	0.00	0.00
PENTACHLOROBIPHENYL	0.00	0.00			0.00
PETROLEUM HYDROCARBONS			0.00	0.00	0.00
PHENANTHRENE	21.32	27.71	53.70	69.80	75.02
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE	0.00	0.00	33.18	39.26	33.18
TOXAPHENE	0.00	0.00	0.00	0.00	0.00

Table 1.3b. James River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	JAMES RIVER AFL		JAMES RIVER BFL		
	16		19		35
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED	12,739.65	23.98	18,759.44	35.30	31,499.09
ZINC, TOTAL	9,530.44	1.90	39,231.44	7.82	48,761.88
ZINC, TOTAL RECOVERABLE	8,925.40	16.21	28,217.30	51.24	37,142.70

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.



Table 1.3c. Potomac River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	POTOMAC RIVER AFL		POTOMAC RIVER BFL		
	41		14		55
	% OF TOTAL CHESAPEAKE BASIN LOAD (lbs/year) BAY WATERSHED LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD (lbs/year) BAY WATERSHED LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL	0.00	0.00	0.00	0.00	0.00
2,4-DICHLOROPHENOL	0.00	0.00	0.00	0.00	0.00
2,4-DIMETHYLPHENOL	0.00	0.00	9.11	4.11	9.11
2,4-DINITROPHENOL	0.00	0.00	0.00	0.00	0.00
2-METHYL-4-CHLOROPHENOL	0.00	0.00	0.00	0.00	0.00
2-METHYLNAPHTHALENE	0.00	0.00			0.00
ACENAPHTHENE	0.00	0.00	0.00	0.00	0.00
ALDRIN	0.00	0.00	0.00	0.00	0.00
ALUMINUM, ACID SOLUABLE	29,252.37	36.31	51,316.16	63.69	80,568.53
ALUMINUM, DISSOLVED	11,018.40	100.00			11,018.40
ALUMINUM, TOTAL	267,910.11	46.03	33,571.64	5.77	301,481.75
ALUMINUM, TOTAL RECOVERABLE	2,643.55	3.80	65,671.11	94.41	68,314.65
AMMONIA+UNIONIZED AMMONIA	160,110.69	2.23	967,043.68	13.49	1,127,154.38
ARSENIC, DISSOLVED	0.00	0.00	0.00	0.00	0.00
ARSENIC, TOTAL	1,842.08	64.91	2.58	0.09	1,844.67
ARSENIC, TOTAL RECOVERABLE	32.62	9.94	173.67	52.91	206.29
BENZO[A]ANTHRACENE	0.00	0.00	0.00	0.00	0.00
BENZO[A]PYRENE	0.10	0.19	0.00	0.00	0.10
BENZO[GHI]PERYLENE	0.00	0.00	0.00	0.00	0.00
CADMIUM, DISSOLVED	24.83	2.41	307.68	29.86	332.51
CADMIUM, TOTAL	14.66	0.19	250.15	3.20	264.81
CADMIUM, TOTAL RECOVERABLE	50.53	3.29	6.12	0.40	56.65
CHLORDANE	0.00	0.00	0.00	0.00	0.00
CHLORPYRIFOS	0.00	0.00	2,878.05	100.00	2,878.05
CHROMIUM, DISSOLVED	984.62	45.07	0.00	0.00	984.62
CHROMIUM, HEXAVALENT	200.15	29.08	67.66	9.83	267.82
CHROMIUM, HEXAVALENT DISSOLVED	53.47	4.12	0.00	0.00	53.47
CHROMIUM, HEXAVALENT TOTAL	0.00	0.00	0.00	0.00	0.00
CHROMIUM, TOTAL	923.26	5.54	16.62	0.10	939.88
CHROMIUM, TOTAL RECOVERABLE	358.11	21.56	64.29	3.87	422.41
CHROMIUM, TRIVALENT			0.01	100.00	0.01
CHRYSENE	0.00	0.00	0.00	0.00	0.00
COPPER, DISSOLVED	4.55	0.08	419.28	7.72	423.83
COPPER, TOTAL	8,892.93	9.58	16,317.65	17.58	25,210.58
COPPER, TOTAL RECOVERABLE	1,674.04	8.24	4,791.34	23.58	6,465.38
DIBENZO(A,H)ANTHRACENE	0.00	0.00	0.00	0.00	0.00
DIELDRIN	0.00	0.00	0.10	100.00	0.10
DIOXIN	0.07	100.00	0.00	0.00	0.07

Table 1.3c. Potomac River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	POTOMAC RIVER AFL		POTOMAC RIVER BFL		
	41		14		55
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)    LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)    LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ENDOSULFAN - ALPHA	0.00	0.00	0.00	0.00	0.00
ENDOSULFAN - BETA	0.00	0.00	0.00	0.00	0.00
ENDRIN ALDEHYDE	0.00	0.00	0.00	0.00	0.00
FLUORANTHENE	0.00	0.00	0.00	0.00	0.00
FLUORENE	0.00	0.00	0.00	0.00	0.00
INDENO(1,2,3-CD)PYRENE	0.00	0.00	0.00	0.00	0.00
IRON, DISSOLVED	1.06	0.01	2,096.41	10.72	2,097.47
IRON, TOTAL	352,893.66	18.26	566,402.01	29.30	919,295.67
IRON, TOTAL RECOVERABLE	6.44	100.00			6.44
LEAD, DISSOLVED	123.11	11.54	8.36	0.78	131.47
LEAD, TOTAL	233.24	1.44	3,287.47	20.35	3,520.72
LEAD, TOTAL RECOVERABLE	172.35	6.04	525.51	18.40	697.87
MANGANESE, DISSOLVED	2,335.20	2.18	104,680.80	97.82	107,016.01
MANGANESE, TOTAL	17,966.37	3.88	84,564.07	18.24	102,530.44
MERCURY, DISSOLVED	11.12	2.30	4.03	0.83	15.15
MERCURY, TOTAL	112.78	16.50	81.51	11.92	194.29
MERCURY, TOTAL RECOVERABLE	8.09	3.45	0.00	0.00	8.09
NAPHTHALENE	1.02	0.01	8,407.45	98.40	8,408.47
NICKEL, DISSOLVED	306.60	2.53	3,923.69	32.34	4,230.30
NICKEL, TOTAL	561.92	1.72	831.19	2.55	1,393.11
NICKEL, TOTAL RECOVERABLE	592.45	25.68	578.50	25.08	1,170.95
NITRITE PLUS NITRATE	1,929,118.39	33.81	1,186,612.78	20.80	3,115,731.17
NITROGEN, AMMONIA TOTAL	823,116.22	0.39	5,358,260.03	2.56	6,181,376.25
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL	563,077.21	3.31	12,988,363.83	76.44	13,551,441.04
PCB 1221	0.00	0.00	0.00	0.00	0.00
PCB 1232	0.00	0.00	0.00	0.00	0.00
PCB 1242	0.00	0.00	0.00	0.00	0.00
PCB 1254	0.00	0.00	0.00	0.00	0.00
PCB-1016	0.00	0.00	0.00	0.00	0.00
PCB-1248	0.00	0.00	0.00	0.00	0.00
PCB-1260	0.15	100.00	0.00	0.00	0.15
PENTACHLOROBIPHENYL	0.00	0.00	0.00	0.00	0.00
PETROLEUM HYDROCARBONS	6,593.79	1.79	42,749.06	11.62	49,342.84
PHENANTHRENE	0.00	0.00	0.00	0.00	0.00
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE	0.00	0.00	0.00	0.00	0.00
TOXAPHENE	0.00	0.00	0.00	0.00	0.00

Table 1.3c. Potomac River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	POTOMAC RIVER AFL		POTOMAC RIVER BFL		
	41		14		55
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED	0.88	0.00	14,814.64	27.88	14,815.52
ZINC, TOTAL	10,962.59	2.19	66,629.49	13.29	77,592.08
ZINC, TOTAL RECOVERABLE	4,155.60	7.55	1,685.55	3.06	5,841.16

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3d. Patuxent River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Patuxent River)		PATUXENT RIVER BFL		
			8		8
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL			0.00	0.00	0.00
2,4-DICHLOROPHENOL			0.00	0.00	0.00
2,4-DIMETHYLPHENOL			0.00	0.00	0.00
2,4-DINITROPHENOL			0.00	0.00	0.00
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPHTHALENE					
ACENAPHTHENE			0.00	0.00	0.00
ALDRIN			540.41	100.00	540.41
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL			0.00	0.00	0.00
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA			72,948.78	1.02	72,948.78
ARSENIC, DISSOLVED					
ARSENIC, TOTAL			0.00	0.00	0.00
ARSENIC, TOTAL RECOVERABLE					
BENZO[A]ANTHRACENE			0.00	0.00	0.00
BENZO[A]PYRENE			0.00	0.00	0.00
BENZO[GHI]PERYLENE			0.00	0.00	0.00
CADMIUM, DISSOLVED					
CADMIUM, TOTAL			7.69	0.10	7.69
CADMIUM, TOTAL RECOVERABLE					
CHLORDANE					
CHLORPYRIFOS					
CHROMIUM, DISSOLVED					
CHROMIUM, HEXAVALENT					
CHROMIUM, HEXAVALENT DISSOLVED					
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL			14.97	0.09	14.97
CHROMIUM, TOTAL RECOVERABLE					
CHROMIUM, TRIVALENT					
CHRYSENE			0.00	0.00	0.00
COPPER, DISSOLVED					
COPPER, TOTAL			325.76	0.35	325.76
COPPER, TOTAL RECOVERABLE					
DIBENZO(A,H)ANTHRACENE			0.00	0.00	0.00
DIELDRIN					
DIOXIN					

Table 1.3d. Patuxent River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Patuxent River)		PATUXENT RIVER BFL		
			8		8
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
<b>CHEMICAL SUBSTANCE</b>					
ENDOSULFAN - ALPHA					
ENDOSULFAN - BETA					
ENDRIN ALDEHYDE					
FLUORANTHENE			0.00	0.00	0.00
FLUORENE			0.00	0.00	0.00
INDENO(1,2,3-CD)PYRENE			0.00	0.00	0.00
IRON, DISSOLVED					
IRON, TOTAL					
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED					
LEAD, TOTAL			44.46	0.28	44.46
LEAD, TOTAL RECOVERABLE			1.91	0.07	1.91
MANGANESE, DISSOLVED					
MANGANESE, TOTAL					
MERCURY, DISSOLVED					
MERCURY, TOTAL			0.00	0.00	0.00
MERCURY, TOTAL RECOVERABLE					
NAPHTHALENE			0.00	0.00	0.00
NICKEL, DISSOLVED					
NICKEL, TOTAL			138.34	0.42	138.34
NICKEL, TOTAL RECOVERABLE			36.50	1.58	36.50
NITRITE PLUS NITRATE			384,135.62	6.73	384,135.62
NITROGEN, AMMONIA TOTAL			79,271.49	0.04	79,271.49
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL			407,443.24	2.40	407,443.24
PCB 1221					
PCB 1232					
PCB 1242					
PCB 1254					
PCB-1016					
PCB-1248					
PCB-1260					
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS			91.17	0.02	91.17
PHENANTHRENE			0.00	0.00	0.00
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE			0.00	0.00	0.00
TOXAPHENE					

Table 1.3d. Patuxent River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Patuxent River)		PATUXENT RIVER BFL		
			8		8
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED					
ZINC, TOTAL			930.83	0.19	930.83
ZINC, TOTAL RECOVERABLE					

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3e. Rappahannock River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	RAPPAHANNOCK AFL		RAPPAHANNOCK BFL		
	5		3		8
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL	0	0	0.00	0.00	0.00
2,4-DICHLOROPHENOL	0	0	0.00	0.00	0.00
2,4-DIMETHYLPHENOL	0	0	0.00	0.00	0.00
2,4-DINITROPHENOL	0	0	0.00	0.00	0.00
2-METHYL-4-CHLOROPHENOL	0	0	0.00	0.00	0.00
2-METHYLNAPHTHALENE					
ACENAPHTHENE	0	0	0.00	0.00	0.00
ALDRIN	0	0	0.00	0.00	0.00
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL					
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA					
ARSENIC, DISSOLVED	23.56	100.00			23.56
ARSENIC, TOTAL	0.79	0.03			0.79
ARSENIC, TOTAL RECOVERABLE	30.15	9.19	1.48	0.45	31.64
BENZO[A]ANTHRACENE	0	0	0.00	0.00	0.00
BENZO[A]PYRENE	0	0	0.00	0.00	0.00
BENZO[GHI]PERYLENE	0	0	0.00	0.00	0.00
CADMIUM, DISSOLVED	0	0	3.79	0.37	3.79
CADMIUM, TOTAL	0.01	1.44E-04			0.01
CADMIUM, TOTAL RECOVERABLE	0.53	0.03			0.53
CHLORDANE	0.00	0.00	0.00	0.00	0.00
CHLORPYRIFOS	0.00	0.00			0.00
CHROMIUM, DISSOLVED	37.93	1.74			37.93
CHROMIUM, HEXAVALENT	0.00	0.00	55.28	8.03	55.28
CHROMIUM, HEXAVALENT DISSOLVED	35.42	2.73			35.42
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL	1.76	0.01	23.48	0.14	25.23
CHROMIUM, TOTAL RECOVERABLE	47.14	2.84			47.14
CHROMIUM, TRIVALENT					
CHRYSENE	0.00	0.00	140.80	75.85	140.80
COPPER, DISSOLVED	20.33	0.37			20.33
COPPER, TOTAL	2.13	0.00			2.13
COPPER, TOTAL RECOVERABLE	104.37	0.51	301.24	1.48	405.61
DIBENZO(A,H)ANTHRACENE	0	0	0.00	0.00	0.00
DIELDRIN	0	0	0.00	0.00	0.00
DIOXIN	0	0			0.00

Table 1.3e. Rappahannock River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	RAPPAHANNOCK AFL		RAPPAHANNOCK BFL		
	5		3		8
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ENDOSULFAN - ALPHA	0	0	0.00	0.00	0.00
ENDOSULFAN - BETA	0	0	0.00	0.00	0.00
ENDRIN ALDEHYDE	0	0	0.00	0.00	0.00
FLUORANTHENE	0	0	0.00	0.00	0.00
FLUORENE	0	0	0.00	0.00	0.00
INDENO(1,2,3-CD)PYRENE	0	0	0.00	0.00	0.00
IRON, DISSOLVED					
IRON, TOTAL			203.44	0.01	203.44
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED	2.28	0.21	33.30	3.12	35.58
LEAD, TOTAL	0	0			0.00
LEAD, TOTAL RECOVERABLE	0	0			0.00
MANGANESE, DISSOLVED					
MANGANESE, TOTAL					
MERCURY, DISSOLVED	0	0	2.75	0.57	2.75
MERCURY, TOTAL	0	0			0.00
MERCURY, TOTAL RECOVERABLE	0	0			0.00
NAPHTHALENE	0	0	0.00	0.00	0.00
NICKEL, DISSOLVED	9.59	0.08	123.07	1.01	132.66
NICKEL, TOTAL	0.68	0.00			0.68
NICKEL, TOTAL RECOVERABLE	2.92	0.13			2.92
NITRITE PLUS NITRATE					
NITROGEN, AMMONIA TOTAL	2,867.79	1.37E-03	69,642.74	0.03	72,510.53
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL					
PCB 1221	0	0	0.00	0.00	0.00
PCB 1232	0	0	0.00	0.00	0.00
PCB 1242	0	0	0.00	0.00	0.00
PCB 1254	0	0	0.00	0.00	0.00
PCB-1016	0	0	0.00	0.00	0.00
PCB-1248	0	0	0.00	0.00	0.00
PCB-1260	0	0	0.00	0.00	0.00
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS					
PHENANTHRENE	0	0	0.00	0.00	0.00
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE	0	0	48.26	57.10	48.26
TOXAPHENE	0	0	0.00	0.00	0.00



Table 1.3e. Rappahannock River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	RAPPAHANNOCK AFL		RAPPAHANNOCK BFL		
	5		3		8
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED	0	0			0.00
ZINC, TOTAL	175.62	0.04	2,809.07	0.56	2,984.69
ZINC, TOTAL RECOVERABLE	336.42	0.61			336.42

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3f. Susquehanna River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
	74		1		75
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)    LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)    LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL	0	0			0.00
2,4-DICHLOROPHENOL	0	0			0.00
2,4-DIMETHYLPHENOL					
2,4-DINITROPHENOL	0	0			0.00
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPHTHALENE					
ACENAPHTHENE					
ALDRIN					
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL	100,179.21	17.21			100,179.21
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA			1,571.51	0.02	1,571.51
ARSENIC, DISSOLVED					
ARSENIC, TOTAL	353.85	12.47			353.85
ARSENIC, TOTAL RECOVERABLE					
BENZO[A]ANTHRACENE					
BENZO[A]PYRENE					
BENZO[GHI]PERYLENE					
CADMIUM, DISSOLVED					
CADMIUM, TOTAL	6,749.88	86.26			6,749.88
CADMIUM, TOTAL RECOVERABLE					
CHLORDANE					
CHLORPYRIFOS					
CHROMIUM, DISSOLVED					
CHROMIUM, HEXAVALENT	78.29	11.37			78.29
CHROMIUM, HEXAVALENT DISSOLVED					
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL	518.61	3.11			518.61
CHROMIUM, TOTAL RECOVERABLE					
CHROMIUM, TRIVALENT					
CHRYSENE					
COPPER, DISSOLVED					
COPPER, TOTAL	7,882.89	8.49			7,882.89
COPPER, TOTAL RECOVERABLE					
DIBENZO(A,H)ANTHRACENE					
DIELDRIN					
DIOXIN					

Table 1.3f. Susquehanna River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
	74		1		75
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
<b>CHEMICAL SUBSTANCE</b>					
ENDOSULFAN - ALPHA					
ENDOSULFAN - BETA					
ENDRIN ALDEHYDE					
FLUORANTHENE					
FLUORENE					
INDENO(1,2,3-CD)PYRENE					
IRON, DISSOLVED	6,162.06	31.52			6,162.06
IRON, TOTAL	112,798.79	5.84			112,798.79
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED					
LEAD, TOTAL	4,028.38	24.94			4,028.38
LEAD, TOTAL RECOVERABLE					
MANGANESE, DISSOLVED					
MANGANESE, TOTAL	11,296.97	2.44			11,296.97
MERCURY, DISSOLVED					
MERCURY, TOTAL	4.62	0.68			4.62
MERCURY, TOTAL RECOVERABLE					
NAPHTHALENE					
NICKEL, DISSOLVED					
NICKEL, TOTAL	3,518.07	10.79			3,518.07
NICKEL, TOTAL RECOVERABLE					
NITRITE PLUS NITRATE			8,661.66	0.15	8,661.66
NITROGEN, AMMONIA TOTAL	2,589,657.53	1.23	2,073.14	0.00	2,591,730.68
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL					
PCB 1221					
PCB 1232					
PCB 1242					
PCB 1254					
PCB-1016					
PCB-1248	0.00	0.00			0.00
PCB-1260					
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS					
PHENANTHRENE					
POLYCHLORINATED BIPHENYLS (PCBS)	0.00	0.00			0.00
PYRENE	0.06	0.07			0.06
TOXAPHENE					

Table 1.3f. Susquehanna River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
	74		1		75
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED					
ZINC, TOTAL	358,509.13	71.50	38.17	0.01	358,547.30
ZINC, TOTAL RECOVERABLE					

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3g. West Chesapeake Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	WEST CHESAPEAKE BASIN, AFL		WEST CHESAPEAKE BASIN, BFL		
	6		27		33
	% OF TOTAL CHESAPEAKE BASIN LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD		TOTAL AFL+BFL BASIN LOAD
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	(lbs/year)
2,4,6-TRICHLOROPHENOL			5.48	2.36	5.48
2,4-DICHLOROPHENOL			2.19	6.80	2.19
2,4-DIMETHYLPHENOL			1.64	0.74	1.64
2,4-DINITROPHENOL			8.22	0.66	8.22
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPHTHALENE					
ACENAPHTHENE			1.92	100.00	1.92
ALDRIN			0.00	0.00	0.00
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL	72,488.35	12.45	12,354.62	2.12	84,842.97
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA	3,954.81	0.06	2,499,363.73	34.86	2,503,318.54
ARSENIC, DISSOLVED					
ARSENIC, TOTAL			147.59	5.20	147.59
ARSENIC, TOTAL RECOVERABLE					
BENZO[A]ANTHRACENE			2.19	3.99	2.19
BENZO[A]PYRENE			10.20	18.64	10.20
BENZO[GH]PERYLENE			3.84	100.00	3.84
CADMIUM, DISSOLVED					
CADMIUM, TOTAL			75.40	0.96	75.40
CADMIUM, TOTAL RECOVERABLE					
CHLORDANE			0.00	0.00	0.00
CHLORPYRIFOS					
CHROMIUM, DISSOLVED			256.65	11.75	256.65
CHROMIUM, HEXAVALENT			35.91	5.22	35.91
CHROMIUM, HEXAVALENT DISSOLVED			0.00	0.00	0.00
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL			11,309.40	67.92	11,309.40
CHROMIUM, TOTAL RECOVERABLE					
CHROMIUM, TRIVALENT					
CHRYSENE			1.92	1.03	1.92
COPPER, DISSOLVED					
COPPER, TOTAL	1,162.86	1.25	45,879.90	49.42	47,042.75
COPPER, TOTAL RECOVERABLE					
DIBENZO(A,H)ANTHRACENE			3.84	100.00	3.84
DIELDRIN			0.00	0.00	0.00
DIOXIN			0.00	0.00	0.00

Table 1.3g. West Chesapeake Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	WEST CHESAPEAKE BASIN, AFL		WEST CHESAPEAKE BASIN, BFL		
	6		27		33
	% OF TOTAL CHESAPEAKE BASIN LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD		TOTAL AFL+BFL BASIN LOAD
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)
ENDOSULFAN - ALPHA					
ENDOSULFAN - BETA					
ENDRIN ALDEHYDE			0.00	0.00	0.00
FLUORANTHENE			1.92	3.43	1.92
FLUORENE			2.19	5.12	2.19
INDENO(1,2,3-CD)PYRENE			3.84	100.00	3.84
IRON, DISSOLVED			11,291.29	57.75	11,291.29
IRON, TOTAL			852,803.30	44.12	852,803.30
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED			121.27	11.36	121.27
LEAD, TOTAL			3,312.50	20.51	3,312.50
LEAD, TOTAL RECOVERABLE					
MANGANESE, DISSOLVED					
MANGANESE, TOTAL			71,753.28	15.48	71,753.28
MERCURY, DISSOLVED					
MERCURY, TOTAL	10.91	1.60	440.43	64.42	451.35
MERCURY, TOTAL RECOVERABLE					
NAPHTHALENE			95.89	1.12	95.89
NICKEL, DISSOLVED					
NICKEL, TOTAL			15,747.82	48.31	15,747.82
NICKEL, TOTAL RECOVERABLE					0.00
NITRITE PLUS NITRATE	420,535.36	7.37	1,025,930.14	17.98	1,446,465.50
NITROGEN, AMMONIA TOTAL	682,494.60	0.33	3,315,468.87	1.58	3,997,963.47
NITROGEN, NITRATE DISSOLVED			204,161.00	100.00	204,161.00
NITROGEN, NITRATE TOTAL			1,513,471.15	8.91	1,513,471.15
PCB 1221					
PCB 1232			0.00	0.00	0.00
PCB 1242			0.00	0.00	0.00
PCB 1254			0.00	0.00	0.00
PCB-1016			0.00	0.00	0.00
PCB-1248			0.00	0.00	0.00
PCB-1260			0.00	0.00	0.00
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS	312,287.04	84.91	4,781.00	1.30	317,068.04
PHENANTHRENE			1.92	2.49	1.92
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE			3.02	3.57	3.02
TOXAPHENE			0.00	0.00	0.00

Table 1.3g. West Chesapeake Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	WEST CHESAPEAKE BASIN, AFL		WEST CHESAPEAKE BASIN, BFL		
	6		27		33
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED			5,407.98	10.18	5,407.98
ZINC, TOTAL			8,254.97	1.65	8,254.97
ZINC, TOTAL RECOVERABLE			10,755.53	19.53	10,755.53

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3h. York River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	YORK RIVER, AFL		YORK RIVER, BFL		
	1		3		4
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)    LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)    LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL	0	0	0.00	0.00	0.00
2,4-DICHLOROPHENOL	0	0	0.00	0.00	0.00
2,4-DIMETHYLPHENOL	0	0	0.00	0.00	0.00
2,4-DINITROPHENOL	0	0	0.00	0.00	0.00
2-METHYL-4-CHLOROPHENOL	0	0	0.00	0.00	0.00
2-METHYLNAPHTHALENE					
ACENAPHTHENE	0	0	0.00	0.00	0.00
ALDRIN	0	0	0.00	0.00	0.00
ALUMINUM, ACID SOLUABLE	0	0			0.00
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL	0	0			0.00
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA	0	0	87,093.40	1.21	87,093.40
ARSENIC, DISSOLVED			0.00	0.00	0.00
ARSENIC, TOTAL	0	0			0.00
ARSENIC, TOTAL RECOVERABLE	0	0	30.39	9.26	30.39
BENZO[A]ANTHRACENE	0	0	0.00	0.00	0.00
BENZO[A]PYRENE	0	0	0.00	0.00	0.00
BENZO[GH]PERYLENE	0	0	0.00	0.00	0.00
CADMIUM, DISSOLVED	0	0	0.00	0.00	0.00
CADMIUM, TOTAL	0	0			0.00
CADMIUM, TOTAL RECOVERABLE			0.00	0.00	0.00
CHLORDANE	0	0	0.00	0.00	0.00
CHLORPYRIFOS					
CHROMIUM, DISSOLVED			70.09	3.21	70.09
CHROMIUM, HEXAVALENT			0.00	0.00	0.00
CHROMIUM, HEXAVALENT DISSOLVED			0.00	0.00	0.00
CHROMIUM, HEXAVALENT TOTAL			0.00	0.00	0.00
CHROMIUM, TOTAL	0	0	348.07	2.09	348.07
CHROMIUM, TOTAL RECOVERABLE			0.00	0.00	0.00
CHROMIUM, TRIVALENT					
CHRYSENE	0	0	0.00	0.00	0.00
COPPER, DISSOLVED			0.00	0.00	0.00
COPPER, TOTAL	0	0			0.00
COPPER, TOTAL RECOVERABLE	0	0	4,336.07	21.34	4,336.07
DIBENZO(A,H)ANTHRACENE	0	0	0.00	0.00	0.00
DIELDRIN	0	0	0.00	0.00	0.00
DIOXIN			0.00	0.00	0.00



Table 1.3h. York River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	YORK RIVER, AFL		YORK RIVER, BFL		
	1		3		4
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
<b>CHEMICAL SUBSTANCE</b>					
ENDOSULFAN - ALPHA	0	0	0.00	0.00	0.00
ENDOSULFAN - BETA	0	0	0.00	0.00	0.00
ENDRIN ALDEHYDE	0	0	0.00	0.00	0.00
FLUORANTHENE	0	0	0.00	0.00	0.00
FLUORENE	0	0	0.00	0.00	0.00
INDENO(1,2,3-CD)PYRENE	0	0	0.00	0.00	0.00
IRON, DISSOLVED					
IRON, TOTAL	0	0			0.00
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED	0	0	0.00	0.00	0.00
LEAD, TOTAL	0	0			0.00
LEAD, TOTAL RECOVERABLE			0.00	0.00	0.00
MANGANESE, DISSOLVED					
MANGANESE, TOTAL	0	0			0.00
MERCURY, DISSOLVED	0	0	3.04	0.63	3.04
MERCURY, TOTAL	0	0			0.00
MERCURY, TOTAL RECOVERABLE			0.00	0.00	0.00
NAPHTHALENE	0	0	0.00	0.00	0.00
NICKEL, DISSOLVED	0	0	60.78	0.50	60.78
NICKEL, TOTAL	0	0			0.00
NICKEL, TOTAL RECOVERABLE			0.00	0.00	0.00
NITRITE PLUS NITRATE	1.28	2.24E-05	333,057.20	5.84	333,058.48
NITROGEN, AMMONIA TOTAL	712.98	3.40E-04	1,201,235.86	0.57	1,201,948.85
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL			321,776.82	1.89	321,776.82
PCB 1221	0	0	0.00	0.00	0.00
PCB 1232	0	0	0.00	0.00	0.00
PCB 1242	0	0	0.00	0.00	0.00
PCB 1254	0	0	0.00	0.00	0.00
PCB-1016	0	0	0.00	0.00	0.00
PCB-1248	0	0	0.00	0.00	0.00
PCB-1260	0	0	0.00	0.00	0.00
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS			0.00	0.00	0.00
PHENANTHRENE	0	0	0.00	0.00	0.00
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE	0	0	0.00	0.00	0.00
TOXAPHENE	0	0	0.00	0.00	0.00

Table 1.3h. York River Basin low load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	YORK RIVER, AFL		YORK RIVER, BFL		
	1		3		4
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED			1,413.38	2.66	1,413.38
ZINC, TOTAL	0	0	4,286.07	0.85	4,286.07
ZINC, TOTAL RECOVERABLE			992.85	1.80	992.85

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3i. Estern Shore Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Eastern Shore)		EASTERN SHORE BFL		
			10		10
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL					
2,4-DICHLOROPHENOL					
2,4-DIMETHYLPHENOL					
2,4-DINITROPHENOL					
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPHTHALENE					
ACENAPHTHENE					
ALDRIN					
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL					
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA			56,562.75	0.78	56,562.75
ARSENIC, DISSOLVED					
ARSENIC, TOTAL					
ARSENIC, TOTAL RECOVERABLE					
BENZO[A]ANTHRACENE					
BENZO[A]PYRENE					
BENZO[GHI]PERYLENE					
CADMIUM, DISSOLVED					
CADMIUM, TOTAL					
CADMIUM, TOTAL RECOVERABLE					
CHLORDANE					
CHLORPYRIFOS					
CHROMIUM, DISSOLVED					
CHROMIUM, HEXAVALENT					
CHROMIUM, HEXAVALENT DISSOLVED					
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL					
CHROMIUM, TOTAL RECOVERABLE					
CHROMIUM, TRIVALENT					
CHRYSENE					
COPPER, DISSOLVED					
COPPER, TOTAL			328.05	0.32	328.05
COPPER, TOTAL RECOVERABLE					
DIBENZO(A,H)ANTHRACENE					
DIELDRIN					
DIOXIN					

Table 1.3i. Estern Shore Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Eastern Shore)		EASTERN SHORE BFL		
			10		10
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
<b>CHEMICAL SUBSTANCE</b>					
ENDOSULFAN - ALPHA					
ENDOSULFAN - BETA					
ENDRIN ALDEHYDE					
FLUORANTHENE					
FLUORENE					
INDENO(1,2,3-CD)PYRENE					
IRON, DISSOLVED					
IRON, TOTAL					
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED					
LEAD, TOTAL					
LEAD, TOTAL RECOVERABLE					
MANGANESE, DISSOLVED					
MANGANESE, TOTAL					
MERCURY, DISSOLVED					
MERCURY, TOTAL					
MERCURY, TOTAL RECOVERABLE					
NAPHTHALENE					
NICKEL, DISSOLVED					
NICKEL, TOTAL			1.52	0.00	1.52
NICKEL, TOTAL RECOVERABLE					
NITRITE PLUS NITRATE			259,201.34	4.53	259,201.34
NITROGEN, AMMONIA TOTAL			1,546,483.57	0.74	1,546,483.57
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL			45,420.71	0.27	45,420.71
PCB 1221					
PCB 1232					
PCB 1242					
PCB 1254					
PCB-1016					
PCB-1248					
PCB-1260					
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS			1,301.59	0.33	1,301.59
PHENANTHRENE					
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE					
TOXAPHENE					

Table 1.3i. Estern Shore Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Eastern Shore)		EASTERN SHORE BFL		
			10		10
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED					
ZINC, TOTAL			24.13	0.00	24.13
ZINC, TOTAL RECOVERABLE					

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3j. James River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	JAMES RIVER AFL		JAMES RIVER BFL		
	16		19		35
	% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
2,4,6-TRICHLOROPHENOL	5,459.82	2.72	61,140.14	30.50	66,599.96
2,4-DICHLOROPHENOL	9,675.91	4.34	122,549.04	54.91	132,224.95
2,4-DIMETHYLPHENOL	9,216.09	4.40	115,293.49	55.01	124,509.58
2,4-DINITROPHENOL	73,020.89	3.07	907,946.98	38.23	980,967.88
2-METHYL-4-CHLOROPHENOL	13,088.35	4.14	158,166.32	50.02	171,254.67
2-METHYLNAPHTHALENE			889.65	95.78	889.65
ACENAPHTHENE	5,728.69	7.73	15,088.37	20.36	20,817.06
ALDRIN	3,271.05	3.54	56,410.33	61.05	59,681.39
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL	102,891.54	17.38			102,891.54
ALUMINUM, TOTAL RECOVERABLE			1,242.59	1.79	1,242.59
AMMONIA+UNIONIZED AMMONIA	0.00	0.00	3,322,800.08	45.70	3,322,800.08
ARSENIC, DISSOLVED	112.82	6.89	1,064.32	64.96	1,177.15
ARSENIC, TOTAL	737.97	8.97	1,363.25	16.57	2,101.22
ARSENIC, TOTAL RECOVERABLE	300.55	7.11	1,972.77	46.66	2,273.32
BENZO[A]ANTHRACENE	26,346.53	4.21	348,078.47	55.59	374,425.00
BENZO[A]PYRENE	5,115.24	4.44	56,944.81	49.45	62,060.05
BENZO[GHI]PERYLENE	7,592.71	4.53	90,864.90	54.26	98,457.61
CADMIUM, DISSOLVED	116.16	5.87	953.02	48.13	1,069.19
CADMIUM, TOTAL	174.21	1.50	747.29	6.44	921.50
CADMIUM, TOTAL RECOVERABLE	31.30	1.66	1,708.66	90.65	1,739.96
CHLORDANE	23,796.36	6.06	225,378.53	57.37	249,174.90
CHLORPYRIFOS			61.02	2.02	61.02
CHROMIUM, DISSOLVED	493.41	8.49	370.89	6.38	864.31
CHROMIUM, HEXAVALENT	881.95	1.20	3,878.99	5.30	4,760.94
CHROMIUM, HEXAVALENT DISSOLVED	2,149.40	9.24	7,280.26	31.29	9,429.66
CHROMIUM, HEXAVALENT TOTAL	57.98	49.61	0.00	0.00	57.98
CHROMIUM, TOTAL	6,694.35	6.68	4,459.44	4.45	11,153.79
CHROMIUM, TOTAL RECOVERABLE	969.91	23.67	2,183.62	53.30	3,153.53
CHROMIUM, TRIVALENT					
CHRYSENE	5,513.19	4.79	56,306.50	48.87	61,819.69
COPPER, DISSOLVED	3,458.02	56.96	1,779.90	29.32	5,237.92
COPPER, TOTAL	4,800.78	4.73	11,316.55	11.15	16,117.33
COPPER, TOTAL RECOVERABLE	1,851.94	7.85	7,993.29	33.89	9,845.23
DIBENZO(A,H)ANTHRACENE	5,592.45	4.59	56,027.28	46.01	61,619.72
DIELDRIN	7,068.18	3.95	108,306.97	60.52	115,375.16
DIOXIN	296.72	7.06	2,214.47	52.68	2,511.19

Table 1.3j. James River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	JAMES RIVER AFL		JAMES RIVER BFL		
	16		19		35
	% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
ENDOSULFAN - ALPHA	94,018.16	4.13	1,298,633.38	57.09	1,392,651.54
ENDOSULFAN - BETA	122,266.96	4.36	1,685,083.13	60.10	1,807,350.10
ENDRIN ALDEHYDE	99,022.49	4.11	1,376,986.55	57.13	1,476,009.04
FLUORANTHENE	4,526.13	4.36	50,102.79	48.32	54,628.92
FLUORENE	4,514.67	4.36	50,053.80	48.33	54,568.47
INDENO(1,2,3-CD)PYRENE	6,985.61	4.23	80,968.15	49.00	87,953.77
IRON, DISSOLVED					
IRON, TOTAL	47,521.92	2.46	329.03	0.02	47,850.94
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED	745.27	10.58	4,108.75	58.31	4,854.02
LEAD, TOTAL	20,431.72	38.09	4,686.95	8.74	25,118.67
LEAD, TOTAL RECOVERABLE	337.30	7.50	2,877.18	63.94	3,214.47
MANGANESE, DISSOLVED					
MANGANESE, TOTAL	42,564.59	9.16	236,573.89	50.91	279,138.48
MERCURY, DISSOLVED	477.52	64.54	176.88	23.91	654.40
MERCURY, TOTAL	40.32	0.71	226.33	4.01	266.65
MERCURY, TOTAL RECOVERABLE	14.39	1.51	912.47	95.57	926.85
NAPHTHALENE	6,936.67	4.06	83,218.79	48.73	90,155.45
NICKEL, DISSOLVED	1,516.39	8.43	7,212.42	40.10	8,728.81
NICKEL, TOTAL	9,848.20	15.53	7,743.61	12.21	17,591.82
NICKEL, TOTAL RECOVERABLE	918.25	14.58	3,252.93	51.65	4,171.18
NITRITE PLUS NITRATE	105,464.63	1.84	58,006.91	1.01	163,471.55
NITROGEN, AMMONIA TOTAL	30,638,002.63	14.61	163,398,337.46	77.91	194,036,340.09
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL	209,264.71	1.23	959,786.65	5.64	1,169,051.36
PCB 1221	50,848.68	4.33	692,621.32	59.04	743,469.99
PCB 1232	81,203.67	4.26	1,107,722.39	58.17	1,188,926.06
PCB 1242	81,203.67	4.26	1,107,690.87	58.17	1,188,894.54
PCB 1254	59,955.18	4.30	817,885.91	58.70	877,841.09
PCB-1016	80,931.45	4.25	1,107,816.92	58.18	1,188,748.37
PCB-1248	80,913.31	4.25	1,107,731.84	58.18	1,188,645.15
PCB-1260	80,913.31	4.25	1,107,731.84	58.18	1,188,645.15
PENTACHLOROBIPHENYL	6.88	7.04			6.88
PETROLEUM HYDROCARBONS			0.00	0.00	0.00
PHENANTHRENE	9,412.59	4.35	118,735.44	54.89	128,148.04
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE	6,996.62	4.32	83,262.89	51.37	90,259.51
TOXAPHENE	79,140.87	3.94	1,212,742.17	60.38	1,291,883.04

Table 1.3j. James River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	JAMES RIVER AFL		JAMES RIVER BFL		
	16		19		35
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED	12,740.95	23.86	18,759.44	35.13	31,500.39
ZINC, TOTAL	9,621.94	1.90	39,235.10	7.76	48,857.04
ZINC, TOTAL RECOVERABLE	8,925.40	15.88	28,335.26	50.41	37,260.66

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.



Table 1.3k. Potomac River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	POTOMAC RIVER AFL		POTOMAC RIVER BFL		
	41		14		55
	% OF TOTAL CHESAPEAKE BASIN LOAD (lbs/year) BAY WATERSHED LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD (lbs/year) BAY WATERSHED LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
2,4,6-TRICHLOROPHENOL	2,024.80	1.01	12,830.38	6.40	14,855.18
2,4-DICHLOROPHENOL	1,799.24	0.81	25,268.25	11.32	27,067.49
2,4-DIMETHYLPHENOL	1,797.77	0.86	23,560.03	11.24	25,357.81
2,4-DINITROPHENOL	7,655.64	0.32	187,374.07	7.89	195,029.71
2-METHYL-4-CHLOROPHENOL	1,975.48	0.62	33,095.12	10.47	35,070.60
2-METHYLNAPHTHALENE	39.20	4.22			39.20
ACENAPHTHENE	1,767.38	2.39	14,044.29	18.95	15,811.67
ALDRIN	413.91	0.45	8,407.49	9.10	8,821.40
ALUMINUM, ACID SOLUABLE	29,252.37	36.31	51,316.16	63.69	80,568.53
ALUMINUM, DISSOLVED	11,213.68	100.00			11,213.68
ALUMINUM, TOTAL	268,226.98	45.30	35,378.26	5.98	303,605.24
ALUMINUM, TOTAL RECOVERABLE	2,643.55	3.80	65,671.11	94.41	68,314.65
AMMONIA+UNIONIZED AMMONIA	187,954.69	2.58	967,043.68	13.30	1,154,998.37
ARSENIC, DISSOLVED	15.17	0.93	139.76	8.53	154.93
ARSENIC, TOTAL	2,004.29	24.36	107.59	1.31	2,111.88
ARSENIC, TOTAL RECOVERABLE	848.74	20.07	883.82	20.90	1,732.57
BENZO[A]ANTHRACENE	1,866.10	0.30	72,565.75	11.59	74,431.85
BENZO[A]PYRENE	1,605.40	1.39	12,007.03	10.43	13,612.43
BENZO[GHI]PERYLENE	1,972.67	1.18	18,508.59	11.05	20,481.26
CADMIUM, DISSOLVED	112.53	5.68	686.47	34.67	799.00
CADMIUM, TOTAL	149.27	1.29	837.09	7.21	986.36
CADMIUM, TOTAL RECOVERABLE	94.07	4.99	41.11	2.18	135.18
CHLORDANE	606.31	0.15	42,844.04	10.91	43,450.36
CHLORPYRIFOS	84.06	2.78	2,878.05	95.14	2,962.11
CHROMIUM, DISSOLVED	1,188.61	20.45	279.52	4.81	1,468.13
CHROMIUM, HEXAVALENT	1,137.85	1.55	228.82	0.31	1,366.66
CHROMIUM, HEXAVALENT DISSOLVED	492.11	2.12	13.86	0.06	505.96
CHROMIUM, HEXAVALENT TOTAL	58.89	50.39	0.00	0.00	58.89
CHROMIUM, TOTAL	2,617.82	2.61	3,417.25	3.41	6,035.07
CHROMIUM, TOTAL RECOVERABLE	829.66	20.25	66.48	1.62	896.14
CHROMIUM, TRIVALENT			31.68	100.00	31.68
CHRYSENE	1,772.23	1.54	12,007.03	10.42	13,779.26
COPPER, DISSOLVED	19.71	0.32	419.28	6.91	438.99
COPPER, TOTAL	9,446.50	9.31	17,069.04	16.82	26,515.54
COPPER, TOTAL RECOVERABLE	2,082.82	8.83	6,313.21	26.77	8,396.03
DIBENZO(A,H)ANTHRACENE	1,959.91	1.61	11,711.53	9.62	13,671.45
DIELDRIN	373.97	0.21	19,147.66	10.70	19,521.64
DIOXIN	197.20	4.69	456.44	10.86	653.64

Table 1.3k. Potomac River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	POTOMAC RIVER AFL		POTOMAC RIVER BFL		
	41		14		55
	% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
ENDOSULFAN - ALPHA	362.29	0.02	264,015.07	11.61	264,377.36
ENDOSULFAN - BETA	364.39	0.01	191,936.98	6.85	192,301.36
ENDRIN ALDEHYDE	497.96	0.02	282,966.16	11.74	283,464.12
FLUORANTHENE	1,810.90	1.75	10,657.90	10.28	12,468.80
FLUORENE	1,786.69	1.73	10,621.02	10.26	12,407.71
INDENO(1,2,3-CD)PYRENE	1,927.89	1.17	16,795.06	10.16	18,722.96
IRON, DISSOLVED	1.09	0.01	2,096.41	10.37	2,097.50
IRON, TOTAL	352,893.66	18.25	566,507.88	29.30	919,401.54
IRON, TOTAL RECOVERABLE	6.44	100.00			6.44
LEAD, DISSOLVED	209.91	2.98	1,058.13	15.02	1,268.05
LEAD, TOTAL	1,406.74	2.62	4,444.31	8.29	5,851.04
LEAD, TOTAL RECOVERABLE	561.15	12.47	669.91	14.89	1,231.05
MANGANESE, DISSOLVED	2,335.20	2.18	104,680.80	97.82	107,016.01
MANGANESE, TOTAL	17,966.37	3.87	84,564.07	18.20	102,530.44
MERCURY, DISSOLVED	18.75	2.53	49.99	6.76	68.74
MERCURY, TOTAL	135.20	2.39	2,823.87	49.97	2,959.07
MERCURY, TOTAL RECOVERABLE	25.09	2.63	0.92	0.10	26.01
NAPHTHALENE	1,732.42	1.01	25,539.01	14.96	27,271.43
NICKEL, DISSOLVED	763.98	4.25	6,903.32	38.38	7,667.30
NICKEL, TOTAL	1,218.05	1.92	1,475.67	2.33	2,693.72
NICKEL, TOTAL RECOVERABLE	1,039.30	16.50	578.50	9.18	1,617.79
NITRITE PLUS NITRATE	1,929,118.39	33.74	1,186,612.78	20.75	3,115,731.17
NITROGEN, AMMONIA TOTAL	828,185.88	0.39	5,358,970.00	2.56	6,187,155.88
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL	563,077.21	3.31	12,988,363.83	76.36	13,551,441.04
PCB 1221	429.87	0.04	128,523.48	10.96	128,953.35
PCB 1232	444.00	0.02	214,105.16	11.24	214,549.17
PCB 1242	444.39	0.02	214,105.16	11.24	214,549.55
PCB 1254	494.44	0.04	154,197.99	11.07	154,692.43
PCB-1016	431.51	0.02	214,223.36	11.25	214,654.88
PCB-1248	447.78	0.02	214,116.98	11.25	214,564.76
PCB-1260	500.25	0.03	214,116.98	11.24	214,617.24
PENTACHLOROBIPHENYL	22.28	22.80	68.57	70.16	90.85
PETROLEUM HYDROCARBONS	6,621.81	1.67	70,682.00	17.86	77,303.82
PHENANTHRENE	1,813.39	0.84	24,744.35	11.44	26,557.74
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE	1,870.22	1.15	17,467.55	10.78	19,337.78
TOXAPHENE	828.80	0.04	214,378.71	10.67	215,207.50

Table 1.3k. Potomac River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	POTOMAC RIVER AFL		POTOMAC RIVER BFL		
	41		14		55
	% OF TOTAL CHESAPEAKE BASIN LOAD (lbs/year)		% OF TOTAL CHESAPEAKE BASIN LOAD (lbs/year)		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	
ZINC, DISSOLVED	84.19	0.16	14,814.64	27.74	14,898.83
ZINC, TOTAL	11,821.56	2.34	66,653.96	13.18	78,475.52
ZINC, TOTAL RECOVERABLE	4,670.71	8.31	1,685.55	3.00	6,356.26

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3I. Patuxent River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Patuxent River)		PATUXENT RIVER BFL		
			8		8
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL			50.10	0.02	50.10
2,4-DICHLOROPHENOL			50.10	0.02	50.10
2,4-DIMETHYLPHENOL			50.10	0.02	50.10
2,4-DINITROPHENOL			250.50	0.01	250.50
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPHTHALENE					
ACENAPHTHENE			50.10	0.07	50.10
ALDRIN			4,801.14	5.20	4,801.14
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL			337.20	0.06	337.20
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA			72,948.78	1.00	72,948.78
ARSENIC, DISSOLVED					
ARSENIC, TOTAL			16.86	0.20	16.86
ARSENIC, TOTAL RECOVERABLE					
BENZO[A]ANTHRACENE			50.10	0.01	50.10
BENZO[A]PYRENE			50.10	0.04	50.10
BENZO[GHI]PERYLENE			50.10	0.03	50.10
CADMIUM, DISSOLVED					
CADMIUM, TOTAL			82.64	0.71	82.64
CADMIUM, TOTAL RECOVERABLE					
CHLORDANE					
CHLORPYRIFOS					
CHROMIUM, DISSOLVED					
CHROMIUM, HEXAVALENT					
CHROMIUM, HEXAVALENT DISSOLVED					
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL			119.64	0.12	119.64
CHROMIUM, TOTAL RECOVERABLE					
CHROMIUM, TRIVALENT					
CHRYSENE			50.10	0.04	50.10
COPPER, DISSOLVED					
COPPER, TOTAL			384.54	0.38	384.54
COPPER, TOTAL RECOVERABLE					
DIBENZO(A,H)ANTHRACENE			50.10	0.04	50.10
DIELDRIN					
DIOXIN					

Table 1.3I. Patuxent River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Patuxent River)		PATUXENT RIVER BFL		
			8		8
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
<b>CHEMICAL SUBSTANCE</b>					
ENDOSULFAN - ALPHA					
ENDOSULFAN - BETA					
ENDRIN ALDEHYDE					
FLUORANTHENE			50.10	0.05	50.10
FLUORENE			50.10	0.05	50.10
INDENO(1,2,3-CD)PYRENE			50.10	0.03	50.10
IRON, DISSOLVED					
IRON, TOTAL					
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED					
LEAD, TOTAL			312.53	0.58	312.53
LEAD, TOTAL RECOVERABLE			8.40	0.19	8.40
MANGANESE, DISSOLVED					
MANGANESE, TOTAL					
MERCURY, DISSOLVED					
MERCURY, TOTAL			3.37	0.06	3.37
MERCURY, TOTAL RECOVERABLE					
NAPHTHALENE			50.10	0.03	50.10
NICKEL, DISSOLVED					
NICKEL, TOTAL			155.20	0.24	155.20
NICKEL, TOTAL RECOVERABLE			141.56	2.25	141.56
NITRITE PLUS NITRATE			388,004.62	6.79	388,004.62
NITROGEN, AMMONIA TOTAL			81,023.57	0.04	81,023.57
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL			407,443.24	2.40	407,443.24
PCB 1221					
PCB 1232					
PCB 1242					
PCB 1254					
PCB-1016					
PCB-1248					
PCB-1260					
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS			148.61	0.04	148.61
PHENANTHRENE			50.10	0.02	50.10
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE			50.10	0.03	50.10
TOXAPHENE					

Table 1.3I. Patuxent River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	(No AFL for Patuxent River)		PATUXENT RIVER BFL		
			8		8
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED					
ZINC, TOTAL			1,021.35	0.20	1,021.35
ZINC, TOTAL RECOVERABLE					

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3m. Rappahannock River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	RAPPAHANNOCK AFL		RAPPAHANNOCK BFL		
	5		3		8
	% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED (lbs/year) LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED (lbs/year) LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL	55.85	2.79E-02	143.56	0.07	199.41
2,4-DICHLOROPHENOL	16.98	7.61E-03	145.33	0.07	162.31
2,4-DIMETHYLPHENOL	16.98	8.10E-03	145.33	0.07	162.31
2,4-DINITROPHENOL	213.87	9.00E-03	1,078.57	0.05	1,292.44
2-METHYL-4-CHLOROPHENOL	15.03	4.75E-03	166.56	0.05	181.59
2-METHYLNAPHTHALENE					
ACENAPHTHENE	12.97	1.75E-02	131.17	0.18	144.13
ALDRIN	5.04	5.45E-03	4.94	5.35E-03	9.98
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL					
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA					
ARSENIC, DISSOLVED	23.56	1.44			23.56
ARSENIC, TOTAL	0.79	0.01			0.79
ARSENIC, TOTAL RECOVERABLE	91.84	2.17	100.14	2.37	191.99
BENZO[A]ANTHRACENE	68.62	0.01	235.64	0.04	304.26
BENZO[A]PYRENE	55.35	0.05	132.80	0.12	188.15
BENZO[GHI]PERYLENE	23.99	0.01	170.12	0.10	194.11
CADMIUM, DISSOLVED	16.21	0.82	7.83	0.40	24.04
CADMIUM, TOTAL	0.01	0.00			0.01
CADMIUM, TOTAL RECOVERABLE	9.65	0.51			9.65
CHLORDANE	4.82	1.23E-03	67.23	0.02	72.05
CHLORPYRIFOS	1.83	0.06			1.83
CHROMIUM, DISSOLVED	37.93	0.65			37.93
CHROMIUM, HEXAVALENT	71.49	0.10	167.18	0.23	238.67
CHROMIUM, HEXAVALENT DISSOLVED	127.83	0.55			127.83
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL	13.32	1.33E-02	106.96	0.11	120.28
CHROMIUM, TOTAL RECOVERABLE	47.14	1.15			47.14
CHROMIUM, TRIVALENT					
CHRYSENE	55.35	0.05	269.79	0.23	325.14
COPPER, DISSOLVED	111.60	1.84			111.60
COPPER, TOTAL	2.13	2.10E-03			2.13
COPPER, TOTAL RECOVERABLE	150.01	0.64	301.24	1.28	451.25
DIBENZO(A,H)ANTHRACENE	100.99	0.08	141.79	0.12	242.78
DIELDRIN	6.77	3.78E-03	4.94	0.00	11.72
DIOXIN	0.02	4.34E-04			0.02

Table 1.3m. Rappahannock River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	RAPPAHANNOCK AFL		RAPPAHANNOCK BFL		
	5		3		8
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ENDOSULFAN - ALPHA	0.96	4.24E-05	4.94	2.17E-04	5.91
ENDOSULFAN - BETA	0.96	3.44E-05	6.72	2.40E-04	7.69
ENDRIN ALDEHYDE	0.05	2.14E-06	11.17	4.63E-04	11.22
FLUORANTHENE	54.60	0.05	136.48	0.13	191.07
FLUORENE	53.85	0.05	131.17	0.13	185.01
INDENO(1,2,3-CD)PYRENE	103.99	0.06	163.04	0.10	267.03
IRON, DISSOLVED					
IRON, TOTAL			508.61	0.03	508.61
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED	26.57	0.3770291	61.54	0.87	88.11
LEAD, TOTAL	0.11	2.10E-04			0.11
LEAD, TOTAL RECOVERABLE	46.22	1.027132104			46.22
MANGANESE, DISSOLVED					
MANGANESE, TOTAL					
MERCURY, DISSOLVED	1.46	1.98E-01	6.56	0.89	8.02
MERCURY, TOTAL	0.02	3.99E-04			0.02
MERCURY, TOTAL RECOVERABLE	1.94	0.20			1.94
NAPHTHALENE	53.09	0.03	125.85	0.07	178.95
NICKEL, DISSOLVED	192.14	1.07	206.29	1.15	398.43
NICKEL, TOTAL	0.68	1.07E-03			0.68
NICKEL, TOTAL RECOVERABLE	368.03	5.84			368.03
NITRITE PLUS NITRATE					
NITROGEN, AMMONIA TOTAL	4,027.99	1.92E-03	69,642.74	0.03	73,670.73
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL					
PCB 1221	80.35	6.85E-03	201.69	0.02	282.03
PCB 1232	9.73	5.11E-04	201.69	0.01	211.42
PCB 1242	9.73	5.11E-04	201.69	0.01	211.42
PCB 1254	95.35	6.84E-03	201.69	0.01	297.03
PCB-1016	7.67	4.03E-04	201.69	0.01	209.36
PCB-1248	5.42	2.85E-04	201.69	0.01	207.11
PCB-1260	5.42	2.85E-04	201.69	0.01	207.11
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS					
PHENANTHRENE	30.50	0.01	205.94	0.10	236.44
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE	53.85	0.03	166.62	0.10	220.47
TOXAPHENE	45.69	0.00	446.71	0.02	492.40



Table 1.3m. Rappahannock River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	RAPPAHANNOCK AFL		RAPPAHANNOCK BFL		
	5		3		8
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED	182.55	0.34			182.55
ZINC, TOTAL	213.13	0.04	2,809.07	0.56	3,022.21
ZINC, TOTAL RECOVERABLE	336.42	0.60			336.42

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3n. Susquehanna River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
	74		1		75
	% OF TOTAL CHESAPEAKE BASIN LOAD (lbs/year)		% OF TOTAL CHESAPEAKE BASIN LOAD (lbs/year)		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	
2,4,6-TRICHLOROPHENOL	77447.19	38.64			77,447.19
2,4-DICHLOROPHENOL	160.86	0.07			160.86
2,4-DIMETHYLPHENOL					
2,4-DINITROPHENOL	739990.84	31.15			739,990.84
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPHTHALENE					
ACENAPHTHENE					
ALDRIN					
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL	100410.98	16.96			100,410.98
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA			1,571.51	0.02	1,571.51
ARSENIC, DISSOLVED					
ARSENIC, TOTAL	353.97	4.30			353.97
ARSENIC, TOTAL RECOVERABLE					
BENZO[A]ANTHRACENE					
BENZO[A]PYRENE					
BENZO[GHI]PERYLENE					
CADMIUM, DISSOLVED					
CADMIUM, TOTAL	7029.60	60.57			7,029.60
CADMIUM, TOTAL RECOVERABLE					
CHLORDANE					
CHLORPYRIFOS					
CHROMIUM, DISSOLVED					
CHROMIUM, HEXAVALENT	66214.27	90.44			66,214.27
CHROMIUM, HEXAVALENT DISSOLVED					
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL	66941.32	66.76			66,941.32
CHROMIUM, TOTAL RECOVERABLE					
CHROMIUM, TRIVALENT					
CHRYSENE					
COPPER, DISSOLVED					
COPPER, TOTAL	8781.64	8.65			8,781.64
COPPER, TOTAL RECOVERABLE					
DIBENZO(A,H)ANTHRACENE					
DIELDRIN					
DIOXIN					

Table 1.3n. Susquehanna River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
	74		1		75
	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	% OF TOTAL CHESAPEAKE BAY WATERSHED LOAD	TOTAL AFL+BFL BASIN LOAD (lbs/year)
<b>CHEMICAL SUBSTANCE</b>					
ENDOSULFAN - ALPHA					
ENDOSULFAN - BETA					
ENDRIN ALDEHYDE					
FLUORANTHENE					
FLUORENE					
INDENO(1,2,3-CD)PYRENE					
IRON, DISSOLVED	6162.06	30.49			6,162.06
IRON, TOTAL	112818.61	5.84			112,818.61
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED					
LEAD, TOTAL	5286.23	9.86			5,286.23
LEAD, TOTAL RECOVERABLE					
MANGANESE, DISSOLVED					
MANGANESE, TOTAL	11296.97	2.43			11,296.97
MERCURY, DISSOLVED					
MERCURY, TOTAL	1596.96	28.26			1,596.96
MERCURY, TOTAL RECOVERABLE					
NAPHTHALENE					
NICKEL, DISSOLVED					
NICKEL, TOTAL	13705.14	21.61			13,705.14
NICKEL, TOTAL RECOVERABLE					
NITRITE PLUS NITRATE			8,661.66	0.15	8,661.66
NITROGEN, AMMONIA TOTAL	2590676.24	1.24	2,129.18	1.02E-03	2,592,805.42
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL					
PCB 1221					
PCB 1232					
PCB 1242					
PCB 1254					
PCB-1016					
PCB-1248	0.00	0.00			0.00
PCB-1260					
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS					
PHENANTHRENE					
POLYCHLORINATED BIPHENYLS (PCBS)	15481.95	100.00			15,481.95
PYRENE	28.64	0.02			28.64
TOXAPHENE					

Table 1.3n. Susquehanna River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
	74		1		75
	% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	
ZINC, DISSOLVED					
ZINC, TOTAL	358591.98	70.89	38.48	0.01	358,630.45
ZINC, TOTAL RECOVERABLE					

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3o. West Chesapeake Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	WEST CHESAPEAKE BASIN, AFL		WEST CHESAPEAKE BASIN, BFL		
	6		27		33
	% OF TOTAL CHESAPEAKE BASIN LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD		TOTAL AFL+BFL BASIN LOAD
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	(lbs/year)
2,4,6-TRICHLOROPHENOL			7,152.06	3.57	7,152.06
2,4-DICHLOROPHENOL			7,176.18	3.22	7,176.18
2,4-DIMETHYLPHENOL			7,175.63	3.42	7,175.63
2,4-DINITROPHENOL			35,821.74	1.51	35,821.74
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPHTHALENE					
ACENAPHTHENE			6,963.33	9.40	6,963.33
ALDRIN			2.67	0.00	2.67
ALUMINUM, ACID SOLUABLE					
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL	72,488.35	12.24	12,359.90	2.09	84,848.26
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA	3,954.81	0.05	2,571,539.80	35.36	2,575,494.61
ARSENIC, DISSOLVED					
ARSENIC, TOTAL			3,643.86	44.28	3,643.86
ARSENIC, TOTAL RECOVERABLE					
BENZO[A]ANTHRACENE			6,965.76	1.11	6,965.76
BENZO[A]PYRENE			6,975.20	6.06	6,975.20
BENZO[GHI]PERYLENE			7,005.25	4.18	7,005.25
CADMIUM, DISSOLVED					
CADMIUM, TOTAL			2,584.95	22.27	2,584.95
CADMIUM, TOTAL RECOVERABLE					
CHLORDANE			26.68	0.01	26.68
CHLORPYRIFOS					
CHROMIUM, DISSOLVED			3,297.89	56.73	3,297.89
CHROMIUM, HEXAVALENT			76.07	0.10	76.07
CHROMIUM, HEXAVALENT DISSOLVED			12,334.52	53.02	12,334.52
CHROMIUM, HEXAVALENT TOTAL					
CHROMIUM, TOTAL			15,560.80	15.52	15,560.80
CHROMIUM, TOTAL RECOVERABLE					
CHROMIUM, TRIVALENT					
CHRYSENE			6,963.55	6.04	6,963.55
COPPER, DISSOLVED					
COPPER, TOTAL	1,162.86	1.15	48,176.44	47.48	49,339.30
COPPER, TOTAL RECOVERABLE					
DIBENZO(A,H)ANTHRACENE			7,004.67	5.75	7,004.67
DIELDRIN			3.92	0.00	3.92
DIOXIN			0.00	0.00	0.00

Table 1.3o. West Chesapeake Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	WEST CHESAPEAKE BASIN, AFL		WEST CHESAPEAKE BASIN, BFL		
	6		27		33
	% OF TOTAL CHESAPEAKE BASIN LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD		TOTAL AFL+BFL BASIN LOAD
CHEMICAL SUBSTANCE	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)	BAY WATERSHED LOAD	BASIN LOAD (lbs/year)
ENDOSULFAN - ALPHA					
ENDOSULFAN - BETA					
ENDRIN ALDEHYDE			3.92	0.00	3.92
FLUORANTHENE			7,148.31	6.89	7,148.31
FLUORENE			7,148.47	6.90	7,148.47
INDENO(1,2,3-CD)PYRENE			7,189.97	4.35	7,189.97
IRON, DISSOLVED			11,949.75	59.13	11,949.75
IRON, TOTAL			852,819.69	44.11	852,819.69
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED			573.27	8.14	573.27
LEAD, TOTAL			17,068.54	31.82	17,068.54
LEAD, TOTAL RECOVERABLE					
MANGANESE, DISSOLVED					
MANGANESE, TOTAL			71,753.28	15.44	71,753.28
MERCURY, DISSOLVED					
MERCURY, TOTAL	25.01	0.44	799.69	14.15	824.70
MERCURY, TOTAL RECOVERABLE					
NAPHTHALENE			7,883.26	4.62	7,883.26
NICKEL, DISSOLVED					
NICKEL, TOTAL			29,269.32	46.15	29,269.32
NICKEL, TOTAL RECOVERABLE					0.00
NITRITE PLUS NITRATE	423,996.66	7.42	1,025,965.49	17.94	1,449,962.15
NITROGEN, AMMONIA TOTAL	683,015.17	0.33	3,326,156.42	1.59	4,009,171.59
NITROGEN, NITRATE DISSOLVED			204,161.00	100.00	204,161.00
NITROGEN, NITRATE TOTAL			1,513,471.15	8.90	1,513,471.15
PCB 1221					
PCB 1232			13.91	0.00	13.91
PCB 1242			13.91	0.00	13.91
PCB 1254			26.39	0.00	26.39
PCB-1016			13.91	0.00	13.91
PCB-1248			13.91	0.00	13.91
PCB-1260			26.39	0.00	26.39
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS	312,287.04	78.90	4,781.00	1.21	317,068.04
PHENANTHRENE			6,964.61	3.22	6,964.61
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE			6,964.43	4.30	6,964.43
TOXAPHENE			166.90	0.01	166.90

Table 1.3o. West Chesapeake Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	WEST CHESAPEAKE BASIN, AFL		WEST CHESAPEAKE BASIN, BFL		
	6		27		33
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED			5,407.98	10.13	5,407.98
ZINC, TOTAL			11,539.91	2.28	11,539.91
ZINC, TOTAL RECOVERABLE			11,268.86	20.05	11,268.86

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.3p. York River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	YORK RIVER, AFL		YORK RIVER, BFL		
	1		3		4
	% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
2,4,6-TRICHLOROPHENOL	0	0	34,147.32	17.04	34,147.32
2,4-DICHLOROPHENOL	0	0	56,347.38	25.25	56,347.38
2,4-DIMETHYLPHENOL	0	0	52,342.78	24.97	52,342.78
2,4-DINITROPHENOL	0	0	421,898.10	17.76	421,898.10
2-METHYL-4-CHLOROPHENOL	0	0	109,714.72	34.70	109,714.72
2-METHYLNAPHTHALENE					
ACENAPHTHENE	0	0	30,317.45	40.91	30,317.45
ALDRIN	0	0	19,089.08	20.66	19,089.08
ALUMINUM, ACID SOLUABLE	0	0			0.00
ALUMINUM, DISSOLVED					
ALUMINUM, TOTAL	0	0			0.00
ALUMINUM, TOTAL RECOVERABLE					
AMMONIA+UNIONIZED AMMONIA	0	0	87,093.40	1.20	87,093.40
ARSENIC, DISSOLVED			282.91	17.27	282.91
ARSENIC, TOTAL	0	0			0.00
ARSENIC, TOTAL RECOVERABLE	0	0	30.39	0.72	30.39
BENZO[A]ANTHRACENE	0	0	169,985.03	27.15	169,985.03
BENZO[A]PYRENE	0	0	32,274.75	28.03	32,274.75
BENZO[GH]PERYLENE	0	0	41,265.25	24.64	41,265.25
CADMIUM, DISSOLVED	0	0	87.80	4.43	87.80
CADMIUM, TOTAL	0	0			0.00
CADMIUM, TOTAL RECOVERABLE			0.00	0.00	0.00
CHLORDANE	0	0	100,130.87	25.49	100,130.87
CHLORPYRIFOS					
CHROMIUM, DISSOLVED			145.42	2.50	145.42
CHROMIUM, HEXAVALENT			557.34	0.76	557.34
CHROMIUM, HEXAVALENT DISSOLVED			867.14	3.73	867.14
CHROMIUM, HEXAVALENT TOTAL			0.00	0.00	0.00
CHROMIUM, TOTAL	0	0	348.07	0.35	348.07
CHROMIUM, TOTAL RECOVERABLE			0.00	0.00	0.00
CHROMIUM, TRIVALENT					
CHRYSENE	0	0	32,274.75	28.01	32,274.75
COPPER, DISSOLVED			282.91	4.66	282.91
COPPER, TOTAL	0	0			0.00
COPPER, TOTAL RECOVERABLE	0	0	4,893.41	20.75	4,893.41
DIBENZO(A,H)ANTHRACENE	0	0	39,172.94	32.17	39,172.94
DIELDRIN	0	0	44,055.47	24.62	44,055.47
DIOXIN			1,038.41	24.70	1,038.41



Table 1.3p. York River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	YORK RIVER, AFL		YORK RIVER, BFL		
	1		3		4
	% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		% OF TOTAL CHESAPEAKE BASIN LOAD BAY WATERSHED LOAD (lbs/year)		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ENDOSULFAN - ALPHA	0	0	617,647.86	27.15	617,647.86
ENDOSULFAN - BETA	0	0	803,994.18	28.68	803,994.18
ENDRIN ALDEHYDE	0	0	650,753.19	27.00	650,753.19
FLUORANTHENE	0	0	29,206.43	28.17	29,206.43
FLUORENE	0	0	29,206.43	28.20	29,206.43
INDENO(1,2,3-CD)PYRENE	0	0	51,057.03	30.90	51,057.03
IRON, DISSOLVED					
IRON, TOTAL	0	0			0.00
IRON, TOTAL RECOVERABLE					
LEAD, DISSOLVED	0	0	263.41	3.74	263.41
LEAD, TOTAL	0	0			0.00
LEAD, TOTAL RECOVERABLE			0.00	0.00	0.00
MANGANESE, DISSOLVED					
MANGANESE, TOTAL	0	0			0.00
MERCURY, DISSOLVED	0	0	8.70	1.18	8.70
MERCURY, TOTAL	0	0			0.00
MERCURY, TOTAL RECOVERABLE			0.00	0.00	0.00
NAPHTHALENE	0	0	45,224.85	26.48	45,224.85
NICKEL, DISSOLVED	0	0	1,192.41	6.63	1,192.41
NICKEL, TOTAL	0	0			0.00
NICKEL, TOTAL RECOVERABLE			0.00	0.00	0.00
NITRITE PLUS NITRATE	1.28	2.23E-05	333,057.20	5.82	333,058.48
NITROGEN, AMMONIA TOTAL	1,019.97	4.86E-04	1,201,235.86	0.57	1,202,255.84
NITROGEN, NITRATE DISSOLVED					
NITROGEN, NITRATE TOTAL			321,776.82	1.89	321,776.82
PCB 1221	0	0	300,368.79	25.61	300,368.79
PCB 1232	0	0	500,599.07	26.29	500,599.07
PCB 1242	0	0	500,599.07	26.29	500,599.07
PCB 1254	0	0	360,462.62	25.87	360,462.62
PCB-1016	0	0	500,599.07	26.29	500,599.07
PCB-1248	0	0	500,599.07	26.29	500,599.07
PCB-1260	0	0	500,623.79	26.29	500,623.79
PENTACHLOROBIPHENYL					
PETROLEUM HYDROCARBONS			0.00	0.00	0.00
PHENANTHRENE	0	0	54,345.08	25.12	54,345.08
POLYCHLORINATED BIPHENYLS (PCBS)					
PYRENE	0	0	45,224.85	27.90	45,224.85
TOXAPHENE	0	0	500,672.73	24.93	500,672.73

Table 1.3p. York River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

# of facilities in estimate	YORK RIVER, AFL		YORK RIVER, BFL		
	1		3		4
	% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		% OF TOTAL CHESAPEAKE BASIN LOAD    BAY WATERSHED (lbs/year)      LOAD		TOTAL AFL+BFL BASIN LOAD (lbs/year)
CHEMICAL SUBSTANCE					
ZINC, DISSOLVED			1,413.38	2.65	1,413.38
ZINC, TOTAL	0	0	4,286.07	0.85	4,286.07
ZINC, TOTAL RECOVERABLE			992.85	1.77	992.85

Note: Empty spaces mean no data available for facilities in a given basin. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Table 1.4. Point Source Load estimates by state.								
Chemical Substance	AVERAGE LOAD ESTIMATES (LBS/YEAR)							
	DC		MD		VA		PA	
	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
2,4,6-TRICHLOROPHENOL			5.48	7,246.98	226.39	115,757.05	0.00	77,447.19
2,4-DICHLOROPHENOL			2.19	7,271.10	30.05	215,757.30	0.00	160.86
2,4-DIMETHYLPHENOL			1.64	7,270.55	220.06	202,327.65		
2,4-DINITROPHENOL			8.22	36,398.36	1,245.77	1,598,862.00	0.00	739,990.84
CHLOROPHENOL					0.00	316,221.58		
2-METHYLNAPHTHALENE					0.00	928.84		
ACENAPHTHENE			1.92	7,054.47	0.00	67,049.28		
ALDRIN			540.41	4,813.28	0.00	87,592.39		
SOLUBLE			29,252.37	29,252.37	51,316.16	51,316.16		
ALUMINUM, DISSOLVED			11,018.40	11,213.68				
ALUMINUM, TOTAL			172,672.04	173,331.41	309,204.42	318,350.84	100,179.21	100,410.98
ALUMINUM, TOTAL RECOVERABLE			2,643.55	2,643.55	66,913.70	66,913.70		
AMMONIA+UNIONIZED AMMONIA			2,794,446.98	2,866,691.54	4,375,563.59	4,404,777.95		
ARSENIC, DISSOLVED					23.56	1,638.54		
ARSENIC, TOTAL			147.59	3,664.80	2,336.64	4,209.81	353.85	353.97
ARSENIC, TOTAL RECOVERABLE			0.00	18.88	328.23	4,209.37		
BENZO[A]ANTHRACENE			2.19	7,084.83	52.73	619,077.17		
BENZO[A]PYRENE			10.30	7,088.26	44.43	108,072.42		
BENZO[GH]PERYLENE			3.84	7,144.56	0.00	160,309.02		
CADMIUM, DISSOLVED					1,030.33	1,980.03		
CADMIUM, TOTAL	243.14	243.14	83.26	2,734.28	746.82	1,595.48	6,752.23	7,032.16
CADMIUM, TOTAL RECOVERABLE			3.78	3.78	1,533.81	1,881.02		
CHLORDANE			0.00	140.76	0.00	392,714.09		
CHLORPYRIFOS					2,878.05	3,024.96		
CHROMIUM, DISSOLVED			256.65	3,486.72	1,927.83	2,326.97		
CHROMIUM, HEXAVALENT	0.00	0.00	51.43	162.75	558.15	6,834.83	78.77	66,216.38
CHROMIUM, HEXAVALENT DISSOLVED			0.00	12,334.52	1,298.56	10,930.58		
CHROMIUM, HEXAVALENT TOTAL RECOVERABLE					12.83	116.87		
CHROMIUM, TOTAL			12,223.69	16,586.19	3,905.44	16,743.54	522.40	66,949.24
CHROMIUM, TOTAL RECOVERABLE			188.82	188.82	1,472.15	3,907.98		
CHROMIUM, TRIVALENT			0.01	31.68				
CHRYSENE			1.92	7,057.53	183.70	108,154.97		
COPPER, DISSOLVED					5,430.12	6,071.43		
COPPER, TOTAL	12,434.57	12,434.57	52,021.64	55,220.04	13,026.26	17,549.63	15,363.19	16,264.29

Chemical Substance	AVERAGE LOAD ESTIMATES (LBS/YEAR)							
	DC		MD		VA		PA	
	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
COPPER, TOTAL RECOVERABLE			496.87	496.87	19,819.35	23,089.05		
E			3.84	7,136.40	0.00	114,625.25		
DIELDRIN			0.00	9.61	0.10	178,958.29		
DIOXIN			0.07	0.07	0.00	4,203.20		
ENDOSULFAN - ALPHA			0.00	0.03	0.00	2,274,682.63		
ENDOSULFAN - BETA			0.00	0.03	0.00	2,803,653.30		
ENDRIN ALDEHYDE			0.00	117.47	0.00	2,410,124.01		
FLUORANTHENE			1.92	7,240.86	53.96	96,452.77		
FLUORENE			2.19	7,239.61	40.66	96,326.08	0.00	0.50
INDENO(1,2,3-CD)PYRENE			3.84	7,308.51	0.00	157,932.34		
IRON, DISSOLVED			11,291.29	11,949.75	2,097.47	2,097.50	6,162.06	6,162.06
IRON, TOTAL RECOVERABLE	284,687.16	284,687.16	1,044,428.50	1,044,445.11	491,037.70	491,448.50	112,798.79	112,818.61
LEAD, DISSOLVED			121.27	573.27	945.98	6,473.58		
LEAD, TOTAL RECOVERABLE	3,283.47	3,283.47	3,358.48	17,546.72	5,309.11	27,346.92	4,200.06	5,460.01
MANGANESE, DISSOLVED			83.65	234.53	2,771.85	4,265.61		
MANGANESE, TOTAL			77,605.50	77,605.50	107,016.01	107,016.01		
MERCURY, DISSOLVED					374,693.04	375,816.70	11,296.97	11,296.97
MERCURY, TOTAL					483.16	739.85		
MERCURY, TOTAL RECOVERABLE	0.16	1,971.01	474.76	857.25	204.10	1,225.57	4.62	1,596.96
NAPHTHALENE			95.89	7,972.97	234.61	951.03		
NICKEL, DISSOLVED					8,448.01	162,790.86	0.01	0.21
NICKEL, TOTAL			17,003.17	30,697.18	12,131.60	17,986.95		
NICKEL, TOTAL RECOVERABLE			12,075.28	19,009.53	3,522.14	13,710.69		
NITRITE PLUS NITRATE			206.79	311.85	2,099.98	5,986.71		
TOTAL	1,035,121.97	1,035,428.64	5,194,752.43	5,202,118.08	511,435.00	515,972.88		
NITROGEN, NITRATE DISSOLVED			6,422,003.84	6,439,557.08	199,603,134.87	199,606,446.63	2,644,827.52	2,647,474.35
TOTAL	11,501,718.58	11,501,718.58	204,161.00	204,161.00				
PCB 1221			2,419,834.20	2,419,834.20	3,069,691.83	3,087,051.52		
PCB 1232					0.00	1,173,074.17		
PCB 1242			0.00	18.43	0.00	1,904,281.19		
PCB 1254			0.00	20.31	0.00	1,904,248.17		
PCB-1016			0.00	38.47	0.00	1,393,281.10		
PCB-1248			0.00	20.31	0.00	1,904,205.27		
PCB-1260			0.00	22.20	0.00	1,904,007.79	0.00	0.00
PENTACHLOROBIPHENYL			0.00	44.13	0.15	1,904,075.55		
					0.00	97.73		

Chemical Substance	AVERAGE LOAD ESTIMATES (LBS/YEAR)							
	DC		MD		VA		PA	
	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
PETROLEUM HYDROCARBONS			341,418.95	366,211.50	26,384.70	29,610.57		
PHENANTHRENE			1.92	7,072.32	75.02	209,228.27	0.00	1.43
POLYCHLORINATED BIPHENYLS (PCBS)							0.00	15,481.95
PYRENE			3.02	7,055.56	81.44	155,001.57	0.06	28.64
TOXAPHENE			0.00	366.25	0.00	2,008,056.32		
ZINC, DISSOLVED			5,407.98	5,407.98	47,727.99	47,995.16		
ZINC, TOTAL	53,190.28	53,190.28	13,414.51	16,791.52	75,170.22	76,184.84	359,606.95	359,690.04
RECOVERABLE			11,699.65	12,212.98	43,369.01	44,002.07		
# of facilities in load estimate	1		78		69		80	

Note: In the loading estimates, Empty spaces represent NOT APPLICABLE, and Zeros can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

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## **CHAPTER 2 - Urban Stormwater Runoff Loadings from the Chesapeake Bay Basin**

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### **INTRODUCTION**

Over the past 25 years, chemical contaminant loads to the Chesapeake Bay and its tributaries have been reduced by placing limits on releases from industrial discharges and other point sources. As a result, stormwater runoff is now thought to be the most significant source of chemical contaminants to many waterbodies in the Chesapeake Bay basin, particularly in urban areas. Precipitation in urban areas falls through polluted air and washes over roads, buildings, parking areas and other features of the urban landscape. When runoff forms, it can transport a variety of chemical contaminants to sewers and streams and potentially to the Chesapeake Bay. The contaminants commonly include metals and organic chemicals used in everything from automobile brake pad linings to pesticides (Table 2.1). Once in the Bay waters, these contaminants may impact the living resources in the Chesapeake Bay basin.

A number of techniques have been developed to estimate annual pollutant loads from urban runoff (Horner et al., 1994). A hydrologic model is typically used to estimate the average annual runoff volume from the urban area, and stormwater monitoring data is used to develop a series of “event mean concentrations” (EMCs) for each chemical whose load is being determined. If one assumes that the EMCs reflect the average concentrations of the chemicals in all runoff produced by an urban area, the estimated average annual chemical contaminant loads can be calculated by multiplying the runoff volume and the EMC concentration.

This chapter summarizes a larger report that presents estimates of annual chemical contaminant loads in stormwater from urban lands in the Chesapeake Bay basin (Gruessner et al., 1998). Combined with the load estimates from other sources in the watershed presented in this report, these stormwater loads will lead to increased understanding of chemical contaminant sources, transport, and fate in the Chesapeake Bay basin (Velinsky, 1996) and will help focus management efforts that seek to protect the health of the basin’s ecosystem, including its human population.

### **TEMPORAL AND SPATIAL COVERAGE**

Annual runoff volumes for urban land in the Chesapeake Bay basin were estimated using Chesapeake Bay Program’s Watershed Model, based on rainfall data for the years 1984-1991.

### ***Urban Stormwater Runoff Loadings***

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EMC values for selected contaminants were calculated based on available data collected by 20 urban jurisdictions in the Chesapeake Bay basin in support of stormwater discharge permitting under the National Pollution Discharge Elimination System (NPDES). Data were collected between 1992 and 1995 and analyzed together.

Table 2.1. Potential Sources for Common Pollutants in Urban Stormwater

<b>Chemical</b>	<b>Some Potential Urban Sources</b>
Aluminum	natural sources, coal combustion
Antimony	gasoline, paints, plastics
Arsenic	fossil fuel combustion, smelting, pesticides
Beryllium	fossil fuel combustion
Cadmium	automobile tires and brakes, sludge and other fertilizers, pesticides
Chromium	metal corrosion, engine part wear, dyes, paints, fertilizers, pesticides
Copper	automobile tires and brakes, building material corrosion, engine part wear, pesticides
Iron	natural sources, automobile corrosion, coke and coal combustion, landfill leachate
Lead	some gasolines, automobile tires, paints
Manganese	automobile tires and brakes, paints, dyes, fertilizers
Mercury	coal combustion, paints, dental wastes
Nickel	metal corrosion, engine part wear
Selenium	coal combustion
Silver	pesticides, dental and medical wastes, coal combustion
Thallium	dyes, pigments
Zinc	automobile tires and brakes, metal corrosion
Polychlorinated Biphenyls	electrical transformers, landfills, lubricants, hydraulic fluids
Polycyclic Aromatic Hydrocarbons (e.g., naphthalene, benzo(a)pyrene)	organic material combustion, automobile seepage, creosote-treated wood
Halogenated Aliphatics (e.g., chlorinated methanes, ethanes, ethylenes, propanes and propenes)	industrial solvents, aerosols
Benzenes, chlorinated benzenes, and toluenes	fuel spills and combustion, pesticides, solvents, asphalt
Phenols	resins, dyes, preservatives, pesticides
Phthalate Esters	plastics, landfills, incinerators
Pesticides (e.g., chlordane, DDTs, acrolein)	land and water application, organic combustion

Adapted from Makepeace, et al., 1995.



## **METHODOLOGY**

### *Calculating Average Annual Runoff Estimates*

The Chesapeake Bay Watershed Model was selected as the source for average annual runoff estimates after a review of several runoff calculation methods (Mandel et al., 1997). The model improves upon the method used in the previous estimate of urban stormwater loads (CBP, 1994a; Olsenholler, 1991) because it uses a well-accepted, supported and calibrated modeling framework to simulate conditions in the entire Chesapeake Bay basin. The same runoff estimates are used by the Chesapeake Bay Program to calculate nutrient loads in the basin.

The Chesapeake Bay Watershed Model estimates runoff for 87 discrete modeling segments in the Bay basin (Figure 2.1), based on land use classifications developed from US EPA's 1990 Environmental Monitoring and Assessment (EMAP) and USGS's Geographic Information Retrieval and Analysis System (GIRAS) land use data (Gutierrez-Magness et al., 1997). Annual runoff values for urban land in each segment were provided by the Chesapeake Bay Program.

### *Calculating EMC Values*

An event mean concentration (EMC) is the flow-weighted average concentration of a chemical in stormwater runoff over the course of a typical rain event. In general, developing EMC values is problematic since suitable rain events are difficult to predict and monitor. At minimum, the rain events must be of sufficient size to produce runoff. To allow for contaminant build-up on the land in the monitored basin, it is also better to sample rain events that follow several days of dry weather. Lastly, to adequately sample fast-moving stormwater in urban areas, sampling must commence soon after the rainfall begins, requiring rapid mobilization of monitoring personnel and equipment.

The previous urban stormwater load estimates were based primarily on limited concentration data from the Priority Pollutant Monitoring Project of the US EPA-led Nationwide Urban Runoff Program or NURP (Athayde et al., 1983; Cole et al., 1983), conducted in the early 1980s. EMC values from NURP were also supplemented with additional values from several other studies (Olsenholler, 1991). The EMC values used in the current study, however, were calculated from monitoring data collected by jurisdictions within the Chesapeake Bay basin in support of NPDES stormwater permitting. Jurisdictions with municipal separate storm sewer systems that serve (or are expected to serve soon) more than 100,000 people were required to monitor stormwater discharges from 5-10 representative land uses during three representative storms each (US EPA, 1993). No other sources of EMC values were used to supplement those derived from the NPDES stormwater data.

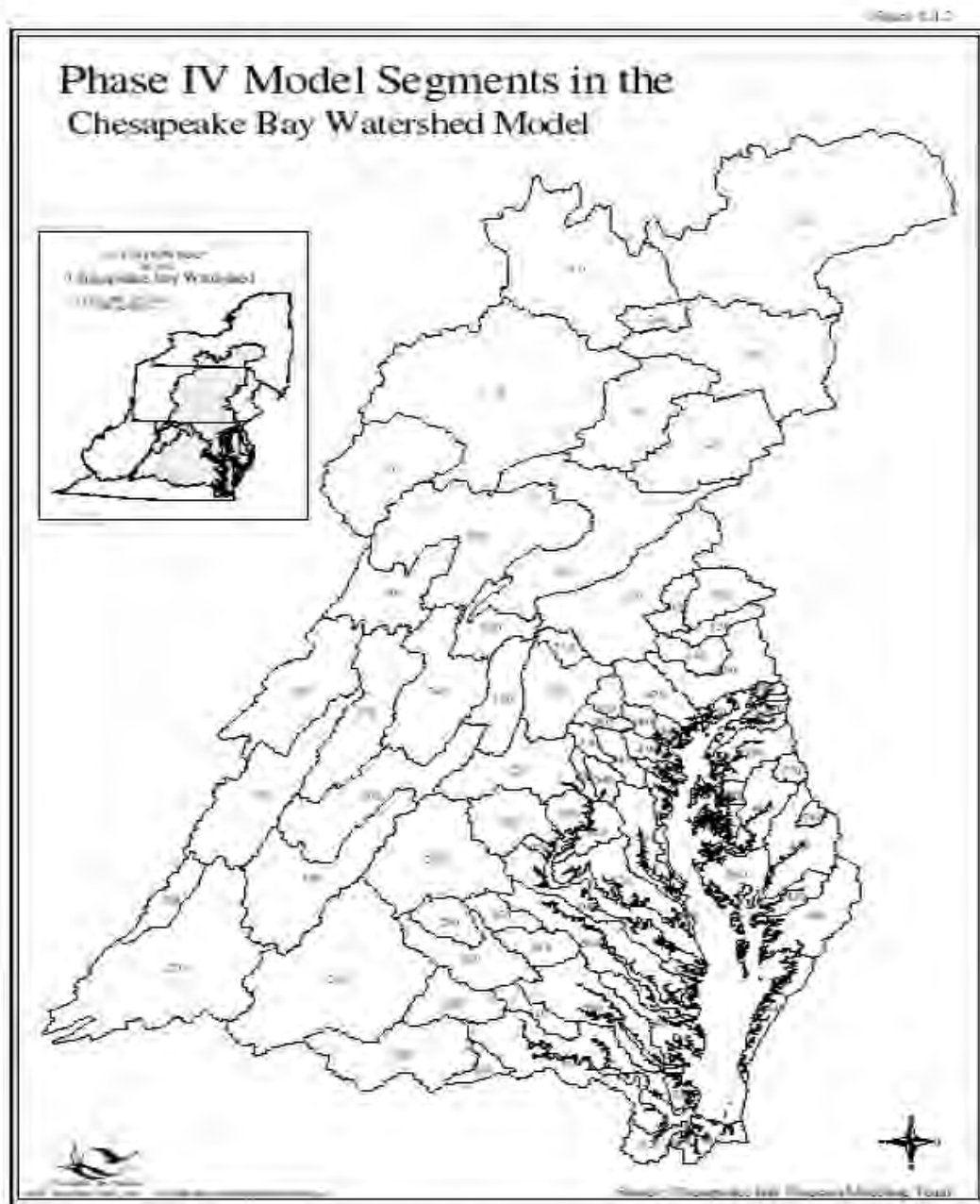


Figure 2.1. Chesapeake Bay Watershed Model segments.  
Source: Chesapeake Bay Program Office.

The NPDES stormwater monitoring data were examined to investigate potential differences between contaminant concentrations in runoff from different general land uses. The results of this analysis are presented in detail in the full report (Gruessner et al., 1998).

Few significant differences or consistent trends in detected chemical concentrations were observed by this analysis. Due to the lack of definitive differences between land uses, data from all land uses were combined to calculate basinwide EMC values.

Basinwide EMC values were calculated from the geometric means of the available concentration data from all of the monitored sites for all chemicals detected in at least three samples. Exceptions were those chemicals that were detected in only one jurisdiction, and those that were suspected to be laboratory contaminants based on quality control data. The geometric mean was chosen over the arithmetic mean because the data approximate a log-normal distribution, similar to the findings in other studies (Horner et al., 1994; Athayde et al., 1983).

Because the analysis results were often below the detection limit for a given chemical, the exact EMCs could not be calculated directly from the data. For below detection limit results, the actual concentration of a given chemical could be anything from zero to the detection limit value. Adapting the method used by Olsenholler (1991) and Cole et al. (1983), lower and upper geometric means were calculated by substituting one-tenth the average available detection limit or the average available detection limit, respectively, for below detection limit results. The average detection limit was used instead of the actual detection limit values because these were not available for all of the individual analyses. One-tenth the average detection limit was selected instead of zero for the lower geometric mean because geometric means cannot be calculated from datasets with zero values. Finally, the EMC value used to calculate the load estimates was defined as the midpoint between the lower and upper geometric means.

### *Calculating Chemical Contaminant Load Estimates*

Chemical contaminant load estimates were calculated by multiplying the average annual runoff volume from urban land for each model segment of the Chesapeake Bay Model by the basinwide EMC concentrations developed from the NPDES stormwater monitoring database. Although not all contaminants were detected at all sites, it was assumed that the EMC values developed from the basinwide data represent the typical occurrence and concentrations of stormwater contaminants throughout the Chesapeake Bay basin.

## **UNCERTAINTY**

The uncertainty in the load estimates cannot be rigorously determined, but a global, order of magnitude estimate of the quantifiable uncertainty is presented below. Other, unquantifiable sources of error are also discussed.

Three main sources of quantifiable error have been identified: modeling error in the average annual runoff estimates, interannual variability in the those estimates, and variability in the measured chemical contaminant concentrations. A comparison of the basinwide urban land use data that is used in the Chesapeake Bay Watershed Model with more detailed county-level land use data suggested an order of magnitude estimate of about 10% error in the amount of urban land and the percentage of impervious surface within those urban areas (Mandel et al., 1997), both of which affect the average annual runoff estimates. There is some additional uncertainty associated with the average annual runoff estimates due to interannual variability in rainfall amounts. To develop an order of magnitude estimate of this uncertainty, 95% confidence intervals were calculated around the mean annual runoff estimates for each segment for each year from 1986-1993. The magnitudes of the confidence intervals in either direction, expressed as the percent of the mean, ranged from 9 to 26% and the average was 16%. Combining the  $\pm 10\%$  estimate of modeling error due to land use with the  $\pm 16\%$  error from the interannual runoff variability, the uncertainty in the calculated runoff values is likely to be about  $\pm 25\%$ .

A similar approach was taken to determine order of magnitude estimates in the uncertainty of the EMC values. To assess the variability in the measured concentrations, 95% confidence intervals were determined around the geometric means of the above detection limit concentrations for each chemical. The magnitude of the confidence intervals in either direction, expressed as the percent of the mean, ranged from 10 to 3365%, and the average was about 354%. Several chemicals had very large confidence intervals due to high variability and low number of values. If the five chemicals from Table 2.4 above that were detected in fewer than five samples (acrolein, ethylbenzene, acenaphthene, di-n-octyl phthalate, indeno(1,2,-cd)pyrene) are removed from the preceding analysis, the average confidence interval drops to 54% of the mean. Note that if the complete dataset that was used to calculate the EMCs (i.e., with one-tenth the average detection level or the average detection level substituted for the “below detection level” results), the average size of the confidence interval drops to about 6% of the geometric mean. To be conservative,  $\pm 54\%$  was selected as an order of magnitude estimate of the uncertainty in the EMC values.

Since the load estimates are calculated from the product of the runoff and EMC values, the combined quantifiable uncertainties suggest that the average annual loads presented here are between one-third and twice the true loads. This is not a true confidence interval around the load estimates, but merely an attempt to quantify some of the uncertainty.

In addition, there are several sources of uncertainty that cannot be quantified. To avoid misapplying data that are not characteristic to this region, EMCs and contaminant loads were not calculated for any chemicals that were not detected at sites within the basin. Several factors may have reduced the number of chemicals that were commonly detected by the NPDES stormwater monitoring, thereby also reducing the number of EMC values and loads that were calculated. The detection limits achieved by most of the laboratories are generally high for measuring ambient concentrations in stormwater. Also, as in all stormwater monitoring, it is difficult to

capture the “first flush” portion of a storm, which may have more chemicals at higher concentrations. Conversely, applying EMC values developed from basinwide data to all urban land in the basin may have artificially created loads for contaminants in some areas where they are not actually present. Lastly, the loads may have been overestimated because the calculations did not account for attenuation of contaminant concentrations during transport from waters that receive runoff to the main tributaries or the Bay.

In summary, the loads presented here are general, Baywide estimates of loads to the Bay’s hydrologic system. Although they are based on the best data available, it is possible that a smaller or larger number of chemicals may be entering receiving waters in runoff, especially from some localized areas. Determining the ultimate fate of these contaminants and their potential effects on living resources will require more complex modeling.

## **DISCUSSION AND COMPARISON WITH 1994 TOXICS LOADING AND RELEASE INVENTORY**

### *Average Annual Runoff Estimates*

Table 2.2 presents the average annual runoff estimates from urban lands for each Chesapeake Bay Program Watershed model segment. The complete runoff data for pervious and impervious urban lands in each segment during each year modeled is presented in the full report (Gruessner et al., 1998).

### *Event Mean Concentrations (EMC)*

Data for 20 of the 23 jurisdictions (counties or cities) in the Chesapeake Bay basin that were required to collect stormwater monitoring data were assembled into a single database. Nearly all of the 115 watersheds monitored in these jurisdictions were sampled on three occasions (others were sampled from one to six times) for a total of 374 samples. Table 2.3 lists the jurisdictions and the predominant land uses in the monitored watersheds. Watersheds draining predominately commercial land uses were most common, followed by those with predominantly medium and low density residential land uses.

Table 2.4 lists the 39 chemicals that were found above method detection limits in at least one sample, the percent of samples above detection limits, and the number of jurisdictions and watersheds where they were detected. Eighteen of these 39 chemicals have been identified as being of some level of concern across the basin by the Chesapeake Bay Program’s Toxics Subcommittee (CBP, 1998), yet only twelve of the 39 were detected in greater than 10% of the samples. The chemicals detected most frequently were zinc, copper, lead and other metals, similar to what was found in the NURP study (Athayde et al., 1983). Other than oil and grease, the organic compounds were infrequently detected. Quality control data for methylene chloride and bis (2-ethylhexyl) phthalate, common laboratory contaminants, indicate that their source is

likely to have been sample contamination.

Table 2.5 lists a series of descriptive statistics for the 29 chemicals that were detected in more than three samples and in more than one jurisdiction (excluding suspected laboratory contaminants). Lower and upper geometric means, calculated by substituting one-tenth the average detection limit or the full average detection limit for below detection limit results, respectively, are presented, as are the EMC values (the midpoints between the lower and upper geometric means). The geometric means for above the detection limit values only (all below detection limit results excluded) are also presented for comparison. The EMC values were lower than the geometric means for the subset of above detection limit data in all but four cases where the chemicals had high average detection limits.

## Urban Stormwater Runoff Loadings

Table 2.2. Average Annual Precipitation Runoff from all Urban Land in the Chesapeake Bay Basin, 1984-1991.

Modeling Segment	Urban Land (acres)	Annual Average Runoff (inches)	Modeling Segment	Urban Land (acres)	Annual Average Runoff (inches)
10	91238	13.6	470	40965	12.7
20	144710	17.7	480	56152	15.1
30	124801	16.3	490	59752	14.6
40	69450	18.9	500	75666	8.7
50	24246	19.9	510	13581	11.9
60	49185	15.7	540	79372	14.5
70	27785	16.1	550	103022	11.5
80	66499	16.3	560	36136	12.2
90	11182	13.4	580	2234	8.1
100	46912	13.0	590	33906	13.1
110	121532	15.8	600	187311	15.2
120	6039	16.0	610	51224	14.1
140	2423	17.6	620	26324	15.1
160	34196	19.6	630	11817	16.5
170	14921	15.4	700	4968	14.1
175	10617	15.7	710	13423	15.8
180	27996	14.9	720	51168	18.0
190	95703	12.1	730	19326	17.0
200	60177	8.9	740	42220	14.4
210	32413	13.8	750	6571	15.4
220	119735	13.6	760	7559	14.1
230	51509	14.9	770	1915	6.2
235	4054	11.7	780	2003	8.6
240	6314	12.6	800	4513	12.5
250	6441	17.1	810	2735	13.6
260	16297	16.9	820	6543	15.3
265	2582	12.7	830	12606	14.3
270	65583	14.1	840	5878	12.8
280	127491	15.5	850	16159	10.4
290	27756	14.3	860	50002	17.7
300	24182	11.0	870	14251	12.0
310	1809	12.4	880	32489	11.9
330	6384	11.1	890	42565	17.1
340	51995	14.0	900	115723	13.7
370	530	11.4	910	68150	11.5
380	6465	10.1	920	53981	8.6
390	3139	11.5	930	1575	8.6
400	12400	11.7	940	11004	13.6
410	19980	12.5	950	33362	19.1
420	18081	12.2	960	110296	18.4
430	14202	9.2	970	6983	12.6
440	11784	10.9	980	37146	10.7
450	38671	12.0	990	5478	10.4

Source: Chesapeake Bay Program Modeling Subcommittee

Table 2.3. Jurisdictions in the Chesapeake Bay Basin With Available NPDES Stormwater Data and Land Uses Sampled

Jurisdiction	Number of Stations Sampled By Predominant Land Use in Watershed <sup>1</sup>					
	Industrial <sup>2</sup>	Commercial	High Density Residential	Medium Density Residential	Low Density Residential	Other <sup>3</sup>
Anne Arundel County	1	2			2	
Baltimore City	1		1	1		
Baltimore County	1	2		1		1
Carroll County		2		1	1	1
Charles County	1	1	1	1		
Chesapeake, VA	1	2		1	3	
Chesterfield County	1			2	1	1
District of Columbia	1	1		3		1
Fairfax County	1	2		3		3
Hampton, VA		3	2		2	
Harford County	1	2		2		
Henrico County	2	2		2		
Howard County	2	1	1	1		
Montgomery County	1	2		1	1	
Newport News, VA	1	3	1	1	4	
Norfolk, VA		5	1		3	
Portsmouth, VA		2		1	2	
Prince Georges County	1	2		2		
Virginia Beach, VA	2	1		2	3	1
Total	18	35	7	25	22	8

<sup>1</sup> General predominant land use category, as reported by the jurisdictions.

<sup>2</sup> This category includes watersheds with predominantly industrial or light industrial/commercial land use.

<sup>3</sup> This category includes watersheds with some urban but predominantly agricultural or park land uses.



## Urban Stormwater Runoff Loadings

Table 2.4. Chemicals Above Detection Level (ADL) in Chesapeake Bay Basin NPDES Stormwater Sampling Data

Chemical	Total Samples	Total Samples ADL	Percent ADL	Jurisdictions ADL	Watersheds ADL
Oil and Grease	350	150	42.9%	18	83
Cyanide	339	24	7.1%	8	17
Total Phenols	337	82	24.3%	12	44
Acrolein	341	1	0.3%	1	1
Chloroform	358	8	2.2%	3	6
Ethylbenzene	358	1	0.3%	1	1
Methylene Chloride <sup>1</sup>	357	96	26.9%	11	46
Toluene	358	4	1.1%	1	4
Phenol	356	3	0.8%	2	3
Acenaphthene <sup>2</sup>	357	1	0.3%	1	1
Anthracene	358	2	0.6%	1	2
Benzo(a)anthracene <sup>2,3</sup>	358	4	1.1%	3	4
Benzo(a)pyrene <sup>2,3</sup>	358	3	0.8%	2	3
3,4-benzofluoranthene	345	6	1.7%	4	5
Benzo(ghi)perylene <sup>2</sup>	358	2	0.6%	1	2
Benzo(k)fluoranthene	358	3	0.8%	2	3
Bis(2-chloroethoxy)methane	358	3	0.8%	2	3
Bis(2-ethylhexyl)phthalate <sup>1</sup>	358	54	15.1%	11	36
Chrysene <sup>2,3</sup>	358	3	0.8%	2	2
1,4-dichlorobenzene	362	21	5.8%	2	14
Di-n-octyl phthalate	358	1	0.3%	1	1
Fluoranthene <sup>3,4</sup>	357	16	4.5%	12	8
Fluorene <sup>2</sup>	358	3	0.8%	3	3
Indeno(1,2,-cd)pyrene <sup>2</sup>	358	1	0.3%	1	1
Phenanthrene <sup>4</sup>	353	11	3.1%	6	9
Pyrene <sup>2</sup>	358	16	4.5%	6	12
Antimony	337	22	6.5%	7	15
Arsenic <sup>2,5</sup>	357	119	33.3%	15	62
Beryllium	337	36	10.7%	9	27
Cadmium <sup>2,3</sup>	361	124	34.3%	15	64
Chromium <sup>2,3</sup>	341	184	54.0%	17	87
Copper <sup>3,4</sup>	361	318	88.1%	19	112
Lead <sup>3,4</sup>	361	241	66.8%	17	97
Mercury <sup>2,3</sup>	338	18	5.3%	9	16
Nickel <sup>2</sup>	356	142	39.9%	15	60
Selenium	353	25	7.1%	7	17
Silver	337	18	5.3%	9	16
Thallium	337	5	1.5%	4	5
Zinc <sup>2,5</sup>	361	5650	97.2%	20	119

<sup>1</sup> Common laboratory contaminant, suspect data.

<sup>2</sup> Draft Revised Chemicals of Potential Concern List

<sup>3</sup> 1990 Toxics of Concern List

<sup>4</sup> Draft Revised Toxics of Concern List

<sup>5</sup> 1990 Chemicals of Potential Concern List

Table 2.5. Descriptive Statistics and EMCs for Selected Chemicals Detected in Chesapeake Bay Basin NPDES Stormwater Sampling Data (µg/L).

<b>Chemical</b>	<b>Min. Detected Value</b>	<b>Max. Detected Value</b>	<b>Geometric Mean of Detected Values</b>	<b>Average Available Detection Limit</b>	<b>Lower Geometric Mean</b>	<b>Upper Geometric Mean</b>	<b>EMC (Middle Geometric Mean)</b>
Oil and Grease	200.00	570000.00	5650.00	4510.00	1330.00	4970.00	3149.00
Cyanide	5.00	60.0	13.56	12.75	1.51	12.80	7.16
Total Phenols	0.13	381.0	15.08	36.10	5.11	29.19	17.15
Chloroform	1.21	6.8	3.33	2.15	0.23	2.17	1.20
Phenol	2.00	9.2	5.53	3.38	0.35	3.39	1.87
Benzo(a)anthracene	2.60	760.0	21.52	3.67	0.38	3.74	2.06
Benzo(a)pyrene	2.60	510.0	27.09	3.22	0.33	3.27	1.80
3,4-benzofluoranthene	1.50	31.6	5.47	3.75	0.39	3.78	2.09
Benzo(k)fluoroanthene	1.20	720.0	22.96	3.37	0.35	3.42	1.89
Bis(2-chloroethoxy)methane	3.70	32.3	15.69	3.89	0.40	3.94	2.17
Chrysene	1.60	820.0	28.15	3.21	0.33	3.27	1.80
1,4-dichlorobenzene	2.00	9.2	3.08	4.80	0.53	4.68	2.61
Fluoranthene	2.40	2290.0	12.30	4.13	0.48	4.34	2.41
Fluorene	1.00	1700.0	43.22	3.11	0.32	3.18	1.75
Phenanthrene	2.00	3840.0	11.05	5.87	0.64	5.98	3.31
Pyrene	2.00	1970.0	6.92	2.97	0.34	3.09	1.72
Antimony	1.00	69.0	7.46	33.44	3.52	30.32	16.92
Arsenic	1.00	310.0	3.38	3.03	0.68	3.14	1.91
Beryllium	0.30	56.0	1.38	1.07	0.14	1.10	0.62
Cadmium	0.10	21.0	0.98	2.76	0.43	1.94	1.18
Chromium	1.00	140.0	5.53	7.63	2.22	6.41	4.32
Copper	2.00	396.0	13.25	10.95	9.85	12.96	11.40
Lead	1.00	368.0	17.92	27.15	9.57	20.58	15.07
Mercury	0.12	1.3	0.23	0.32	0.04	0.31	0.17
Nickel	2.00	110.0	9.46	16.27	3.28	13.10	8.19
Selenium	1.00	9.0	2.29	24.73	2.46	20.89	11.68
Silver	0.20	290.0	2.62	4.31	0.47	4.20	2.34
Thallium	1.00	51.0	7.66	48.28	4.86	46.97	25.92
Zinc	3.00	1078.0	96.17	41.34	88.14	93.95	91.04

See text for description of how geometric means were calculated.

## *Urban Stormwater Runoff Loadings*

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Table 2.6 lists the EMC values from Table 2.1 alongside those used in a previous estimate of chemical contaminant loads in stormwater to the Chesapeake Bay (Olsenholler, 1991). In general, the EMCs calculated for this report tended to be higher for organic compounds and slightly lower for metals. One notably large difference is in the EMC values for lead, where the newly calculated EMC value is more than four times larger than the one used previously. The previous study reduced the EMC value for lead developed from the NURP study, assuming that lead from gasoline sources has been reduced dramatically since the early 1980s when the NURP data were collected (Cole et al., 1983). The more recent data indicate that this assumption may not have been warranted. In general, the new EMC values should better reflect recent conditions within the Chesapeake Bay basin.

### *Chemical Contaminant Load Estimates*

Tables 2.7a and 2.7b present the average annual load estimates for chemical contaminants in stormwater runoff. These estimates represent loads in stormwater runoff reaching any receiving waters and have not been adjusted to reflect attenuation during transport to the mainstem Bay. The total loads are presented first, followed by loads for each major sub-basin. The loads are also further divided into above or below the “fall line” loads. The fall line marks the boundary of two physiographic provinces (roughly following the western edges of Richmond, VA, Washington, DC and Baltimore, MD), and generally indicates the upstream extent of tidal action in the Bay’s tributaries.

Table 2.8 summarizes the current total load estimates for the entire Bay basin and, for selected chemicals, compares them to those from the previous estimate (CBP, 1994a; Olsenholler, 1991). Because the models used in these studies tend to predict similar runoff volumes (Mandel et al., 1997), the two sets of load estimates compare as would be expected from the patterns in the EMC values discussed above. Namely, the loads for organic compounds presented here are generally higher than those from the previous study and the loads for metals are generally lower.

The load estimate for “oil and grease” is particularly high. “Oil and grease” is a collective term used for a group of related petroleum hydrocarbons that are measured together. It includes several parameters whose loads were also calculated individually (e.g., PAHs such as fluorene and benzo(a)pyrene). The sources of these hydrocarbons include direct seepage from engines, other automobile-related activities, and general fossil fuel combustion (Shepp, 1996; Makepeace et al., 1995). Also notable is the high estimated load for lead. The previous estimate of urban stormwater loads assumed that lead in stormwater would be reduced greatly from the early 1980s when the NURP data was collected, yet this does not appear to be the case.

Table 2.6. Comparison of EMC Values With Those From a Previous Estimate Contaminant Loads in the Chesapeake Bay Basin (µg/L).

<b>Chemical</b>	<b>Current Study EMC</b>	<b>Previous Load Estimate EMC<sup>1</sup></b>
Oil and Grease	3149.04	
Cyanide	7.16	9.9
Total Phenols	17.15	
Chloroform	1.20	
Phenol	1.87	
Benzo(a)anthracene	2.06	0.087
Benzo(a)pyrene	1.80	0.098
3,4-benzofluoranthene	2.09	
Benzo(k)fluroanthene	1.89	
Bis(2-chloroethoxy)methane	2.17	
Chrysene	1.80	0.25
1,4-dichlorobenzene	2.61	
Fluoranthene	2.41	0.36
Fluorene	1.75	0.08
Phenanthrene	3.31	0.32
Pyrene	1.72	0.28
Antimony	16.92	2.5
Arsenic	1.91	4.4
Beryllium	0.62	14.6
Cadmium	1.18	1.1
Chromium	4.32	6.3
Copper	11.40	17.6
Lead	15.07	3.8
Mercury	0.17	0.2
Nickel	8.19	12.5
Selenium	11.68	22.1
Silver	2.34	
Thallium	25.92	2.7
Zinc	91.04	96.8

<sup>1</sup> Values from CBP, 1994; Olsenholler, 1991

Table 2.7a. Average Annual Chemical Contaminant Loads in Stormwater Runoff

AFL=Above Fall Line, BFL=Below Fall Line

All values in Kilograms

All values in kilograms														
Chemical	Chesapeake Bay			Susquehanna	Western Shore			Eastern Shore	Patuxent			Potomac		
	Total				MD	MD								
	AFL	BFL	Total	Total (All AFL)	AFL	BFL	Total	Total (All AFL)	AFL	BFL	Total	AFL	BFL	Total
Oil and Grease	8,437	6,772	1.52 x 10 <sup>7</sup>	4,519	34	1,297	1,332	581	259	232	491	2,039	2,065	4,104
Cyanide	3,209	2,576	5,785	1,719	13	493	507	221	99	88	187	776	785	1,561
Total Phenols	19,172	15,389	34,561	10,268	78	2,948	3,026	1,320	589	527	1,115	4,634	4,692	9,326
Chloroform	45,952	36,885	82,836	24,610	187	7,066	7,253	3,164	1,411	1,262	2,673	11,106	11,245	22,351
Phenol	5,009	4,021	9,030	2,683	20	770	791	345	154	138	291	1,211	1,226	2,437
Benzo(a)anthracene	5,522	4,432	9,954	2,957	23	849	872	380	170	152	321	1,335	1,351	2,686
Benzo(a)pyrene	4,833	3,879	8,713	2,588	20	743	763	333	148	133	281	1,168	1,183	2,351
3,4-benzofluoranthene	5,590	4,487	10,077	2,994	23	860	882	385	172	154	325	1,351	1,368	2,719
Benzo(k)fluoranthene	5,051	4,054	9,105	2,705	21	777	797	348	155	139	294	1,221	1,236	2,457
Bis(2-chloroethoxy)methane	5,815	4,667	10,482	3,114	24	894	918	400	179	160	338	1,405	1,423	2,828
Chrysene	4,824	3,872	8,696	2,583	20	742	761	332	148	133	281	1,166	1,180	2,346
1,4-dichlorobenzene	6,985	5,606	12,591	3,741	28	1,074	1,102	481	214	192	406	1,688	1,709	3,397
Fluoranthene	6,453	5,180	11,634	3,456	26	992	1,019	444	198	177	375	1,560	1,579	3,139
Fluorene	4,687	3,762	8,450	2,510	19	721	740	323	144	129	273	1,133	1,147	2,280
Phenanthrene	8,879	7,127	16,006	4,755	36	1,365	1,401	611	273	244	516	2,146	2,173	4,319
Pyrene	4,597	3,690	8,287	2,462	19	707	726	317	141	126	267	1,111	1,125	2,236
Antimony	45,336	36,390	81,726	24,280	185	6,971	7,156	3,122	1,392	1,245	2,637	10,957	11,095	22,052
Arsenic	5,120	4,109	9,229	2,742	21	787	808	353	157	141	298	1,237	1,253	2,490
Beryllium	1,662	1,334	2,996	890	7	256	262	114	51	46	97	402	407	808
Cadmium	3,165	2,541	5,706	1,695	13	487	500	218	97	87	184	765	775	1,540
Chromium	11,563	9,282	20,845	6,193	47	1,778	1,825	796	355	318	673	2,795	2,830	5,624
Copper	30,549	24,521	55,069	16,361	125	4,697	4,822	2,104	938	839	1,777	7,383	7,476	14,859
Lead	40,386	32,417	72,803	21,630	165	6,210	6,375	2,781	1,240	1,109	2,349	9,761	9,883	19,644
Mercury	464	372	837	249	2	71	73	32	14	13	27	112	114	226
Nickel	21,953	17,621	39,574	11,757	90	3,376	3,465	1,512	674	603	1,277	5,306	5,372	10,678
Selenium	31,282	25,109	56,391	16,754	128	4,810	4,938	2,154	960	859	1,820	7,561	7,655	15,216
Silver	6,259	5,024	11,284	3,352	26	962	988	431	192	172	364	1,513	1,532	3,045
Thallium	69,442	55,739	125,181	37,191	283	10,678	10,961	4,782	2,132	1,908	4,039	16,784	16,994	33,777
Zinc	243,935	195,801	439,736	130,644	995	37,508	38,503	16,798	7,488	6,701	14,190	58,957	59,695	118,652

Table 2.7b. Average Annual Chemical Contaminant Loads in Stormwater Runoff

AFL=Above Fall Line, BFL=Below Fall Line

All values in Kilograms, except Oil and Grease in 10002 of Kg.

	Western Shore VA	Eastern Shore VA	Rappahannock			York			James		
Chemical	Total (All BFL)	Total (All BFL)	AFL	BFL	Total	AFL	BFL	Total	AFL	BFL	Total
Oil and Grease	922	42	249	143	392	166	144	310	1,171	1,348	2,518
Cyanide	351	16	95	54	149	63	55	118	445	513	958
Total Phenols	2,095	94	566	325	891	377	326	704	2,661	3,062	5,723
Chloroform	5,021	226	1,356	778	2,134	904	782	1,686	6,377	7,339	13,716
Phenol	547	25	148	85	233	99	85	184	695	800	1,495
Benzo(a)anthracene	603	27	163	94	256	109	94	203	766	882	1,648
Benzo(a)pyrene	528	24	143	82	224	95	82	177	671	772	1,443
3,4-benzofluoranthene	611	28	165	95	260	110	95	205	776	893	1,668
Benzo(k)fluoranthene	552	25	149	86	235	99	86	185	701	807	1,508
Bis(2-chloroethoxy)methane	635	29	172	99	270	114	99	213	807	929	1,736
Chrysene	527	24	142	82	224	95	82	177	669	770	1,440
1,4-dichlorobenzene	763	34	206	118	324	137	119	256	969	1,116	2,085
Fluoranthene	705	32	190	109	300	127	110	237	896	1,031	1,926
Fluorene	512	23	138	79	218	92	80	172	650	749	1,399
Phenanthrene	970	44	262	150	412	175	151	326	1,232	1,418	2,650
Pyrene	502	23	136	78	214	90	78	169	638	734	1,372
Antimony	4,954	223	1,338	768	2,106	892	771	1,664	6,291	7,241	13,532
Arsenic	559	25	151	87	238	101	87	188	710	818	1,528
Beryllium	182	8	49	28	77	33	28	61	231	265	496
Cadmium	346	16	93	54	147	62	54	116	439	506	945
Chromium	1,264	57	341	196	537	228	197	424	1,605	1,847	3,451
Copper	3,338	150	901	518	1,419	601	520	1,121	4,239	4,879	9,118
Lead	4,413	199	1,192	684	1,876	795	687	1,482	5,605	6,450	12,055
Mercury	51	2	14	8	22	9	8	17	64	74	139
Nickel	2,399	108	648	372	1,020	432	373	806	3,046	3,506	6,553
Selenium	3,418	154	923	530	1,453	616	532	1,148	4,341	4,996	9,337
Silver	684	31	185	106	291	123	106	230	869	1,000	1,868
Thallium	7,588	342	2,049	1,176	3,225	1,367	1,181	2,548	9,637	11,091	20,727
Zinc	26,656	1,201	7,198	4,132	11,330	4,801	4,150	8,951	33,852	38,959	72,811

### ***Urban Stormwater Runoff Loadings***

Table 2.8. Comparison of Baywide Loads With Those From a Previous Estimate of Contaminant Loads in the Chesapeake Bay Basin.

<b>Chemical</b>	<b>Current Study Total Load (Kg/yr)</b>	<b>Previous Study Total Load<sup>1</sup> (Kg/yr)</b>
Oil and Grease	15,209,876	
Cyanide	34,561	58,968
Total Phenols	82,836	
Chloroform	5,785	
Phenol	9,030	
Benzo(a)anthracene	9,954	168
Benzo(a)pyrene	8,713	181
3,4-benzofluoranthene	10,077	
Benzo(k)fluoranthene	9,105	
Bis(2-chloroethoxy)methane	10,482	
Chrysene	8,696	454
1,4-dichlorobenzene	12,591	
Fluoranthene	11,633	680
Fluorene	8,450	
Phenanthrene	16,006	
Pyrene	8,287	
Antimony	81,726	14,515
Arsenic	9,229	25,855
Beryllium	2,996	86,184
Cadmium	5,706	6,350
Chromium	20,845	37,195
Copper	55,069	104,328
Lead	72,803	22,226
Mercury	837	1,179
Nickel	39,574	72,576
Selenium	56,391	131,544
Silver	11,284	
Thallium	125,181	15,876
Zinc	439,736	589,680

<sup>1</sup> Values from CBP, 1994; Olsenholler, 1991 converted from pounds.

## **RECOMMENDATIONS**

The load estimates for chemical contaminants in stormwater runoff from urban lands in the Chesapeake Bay watershed presented here reflect runoff estimates that are consistent with those used for other Bay Program efforts and stormwater monitoring data collected from urban areas within the basin. As such, they improve upon a previous load estimate that used other runoff values and contaminant concentrations that were measured at sites across the country.

It is important to remember that, since the same EMC values were applied to all urban land uses throughout the Chesapeake Bay basin, the differences in estimated loads from one part of the basin to another are due only to differences in the amount of urban land and the degree of imperviousness within it. The loads do not indicate which urban areas are likely to be contributing chemical contaminants out of proportion to their size. Also, users of this report may want to exercise caution when applying EMC values and load estimates for those chemicals that were detected in only a few samples.

The load estimates show that certain metals (arsenic, cadmium, copper, lead, nickel, and zinc) are commonly detected in urban stormwater in the Chesapeake Bay basin, confirming what was predicted from the local and national stormwater data (Olsenholler, 1991) and from what is known about the typical sources of metals in urban areas (Table 2.1; Makepeace et al., 1995). The general class of hydrocarbons measured as “oil and grease” was also commonly detected and may be of Baywide concern as well.

Other metals and a number of organic compounds were detected less often and in fewer areas. These chemicals may be more localized problems or they may have not been effectively captured by the limited sampling in each watershed, given the high variability in rainfall amounts and antecedent conditions. Polycyclic Aromatic Hydrocarbons or PAHs (a subset of “oil and grease”), including 3,4-benzofluoranthene, fluoranthene, phenanthrene, and pyrene, were the most commonly detected organic compounds. Their sources are primarily seepage from automobiles and organic matter combustion (Shepp, 1996; Schueler, 1994). It is interesting to note that no pesticides or PCBs were found in Chesapeake Bay basin stormwater, even though these chemicals have been observed in other studies (Makepeace et al., 1995).

Further improvements to urban stormwater load estimates will require both better runoff volume estimates and more accurate EMC values that are specific to a particular geographic region, or even to each land use within that region. Runoff estimates could be improved somewhat by developing better urban land use data for the watershed model. Improved EMC values may be developed by expanding and further analyzing the combined dataset assembled for this study as additional NPDES stormwater monitoring data from urban areas is collected. The NPDES stormwater monitoring data will provide a more accurate picture of contaminants in stormwater if detection limits can be lowered by using refined sampling and analytical techniques.



### ***Urban Stormwater Runoff Loadings***

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It is difficult to predict how the contaminants entering the Bay and its tributaries in urban stormwater will ultimately affect the Bay's living resources. Further study of the specific sources of the chemicals commonly detected in NPDES stormwater monitoring, along with their transport and fate, may be warranted in certain urban areas. These estimates of contaminant loads in urban stormwater, when combined with similar estimates of loads from other sources, can be used to assess the relative importance of various sources of contaminants to the Bay system and focus management efforts appropriately.

If, as suspected, urban stormwater is found to be a significant contributor of chemical contaminants relative to other sources, these load estimates provide a starting point for determining which chemicals should be targeted for general source reduction activities such as pollution prevention or best management practices. The analysis of the NPDES stormwater data presented here, along with other information, may also help determine which areas of the basin are in need of further study. Intensive monitoring and modeling in a particular subwatershed may then provide enough information about chemical loads, transport, and fate to allow reduction targets to be set for that subwatershed.

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## CHAPTER 3 - Atmospheric Deposition Loadings

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The objective of this chapter is to describe atmospheric deposition processes and to synthesize currently available information to estimate atmospheric deposition loadings of chemical contaminants to the Chesapeake Bay surface waters below the fall-lines. This chapter updates and expands the *1994 Chesapeake Bay Basin Toxics Loading and Release Inventory* (CBP, 1994a) using recent field measurements and improved theoretical understanding of deposition processes.

### INTRODUCTION

#### Defining Atmospheric Deposition Processes

##### *Wet Deposition*

Wet deposition includes all processes that transport atmospheric chemicals to the Earth's surface during precipitation events. While precipitation events include rain, snow, sleet, fog impaction, and perhaps dew formation, rainfall contributes the vast majority of wet deposition to the Chesapeake Bay region and is assumed in this chapter to be the sole wet deposition form to the Chesapeake Bay. Transport of chemicals by precipitation depends both upon the concentration of chemical in the raindrops and upon the precipitation amount. Chemicals may be incorporated into cloud droplets and into falling drops below the clouds (see review by Poster and Baker, 1997). Gaseous contaminants adsorb to solid aerosol particles and dissolve into liquid droplets. Mass transfer rates of gases into hydrometers are rapid relative to droplet transport times, allowing gas scavenging to be modeled as an equilibrium process. Aerosol particles are incorporated into droplets during initial formation (i.e., they act as condensation nuclei) or are scavenged into existing droplets within or below clouds. The efficiency with which particles and their associated contaminants are incorporated into raindrops depends upon the size distribution and hygroscopicity of the particle population, the droplet size spectra, and the amount of atmospheric turbulence during the precipitation event.

##### *Dry Aerosol Deposition*

Dry aerosol deposition results from the transport of aerosol particles to the Earth's surface. Several mechanisms deposit particles to terrestrial and aquatic surfaces, ranging from eddy diffusion of small ( $<0.1\ \mu\text{m}$  diameter) particles to gravitational settling of large ( $>10\ \mu\text{m}$ )

particles. These deposition processes strongly depend upon the size distribution of the ambient aerosol particles and upon the extent of turbulence near the deposition surface (see Zufall and Davidson, 1997 and Ondov et al., 1997 for reviews of dry aerosol deposition processes). Dry aerosol deposition rates to water surfaces are generally lower than those to adjacent terrestrial surfaces due to enhanced turbulent transfer over the rougher vegetation and soils. Similarly, dry aerosol deposition fluxes are larger under the unstable meteorological conditions that exist when cooler air moves over warm water. Changes in particle size distribution, which may significantly alter dry aerosol deposition fluxes, result from growth of hygroscopic particles under high humidity (Ondov et al., 1997), particle coagulation, or changes in emission size distributions.

### *Gas Exchange*

Volatile chemicals exchange across the air-water interface by passive diffusion (see Eisenreich et al., 1997 and Bidleman and M'Connell, 1995 for recent reviews of gas exchange). Exchange of simple gases such as oxygen and carbon dioxide across the air-water interface are well studied, and form the conceptual basis for exchange of volatile chemical contaminants. Overall net gas exchange fluxes are calculated as the product of a diffusional gradient and a mass transfer coefficient. The diffusion gradient is the difference between the measured dissolved chemical concentration in the surface water and that dissolved concentration that is in equilibrium with the measured gas phase concentration in the overlying air mass. For semivolatile contaminants, Henry's Law describes the equilibrium condition. Chemical compound-specific Henry's Law equilibrium constants are quite sensitive to temperature (Bamford et al., 1999a), resulting in a temperature-dependent diffusional gradient. The diffusional mass transfer coefficient depends upon the molecular diffusivity of the compound in water and air and upon the extent of turbulence at the air-water interface (as commonly parameterized by correlations with wind speed; Nelson et al., 1998).

The process of gas exchange actively transports volatile chemicals concurrently in both directions across the air-water interface. In this chapter, net gas exchange fluxes, equal to the difference between the gross absorptive and volatilization fluxes, are presented. To more accurately demonstrate the coupling between the atmosphere and surface waters, gross absorptive fluxes are included in the discussion of relative loadings and mass balances in Chapter 8.

## **TEMPORAL AND SPATIAL COVERAGE**

In this report, we consider the CBADS sampling sites to represent the regional background deposition signal weakly or unaffected by localized urban influences. Ambient concentrations and deposition fluxes at these sites are similar to those reported at remote sites in the Great Lakes (Baker et al., 1997; Hoff et al., 1996), supporting this designation as regional background sites. Recently, the influence of elevated contaminant levels in urban atmospheres on enhanced deposition to adjacent coastal waters has been demonstrated (Offenberg and Baker, 1997; Gustafson and Dickhut, 1997). To quantify this enrichment in the Chesapeake Bay urban

areas, the Atmospheric Exchange Over Lakes and Seas (AEOLOS) program conducted a series of intensive sampling campaigns in and downwind of the Baltimore metropolitan area. While much of the AEOLOS data are not yet final, initial results confirm enhanced deposition in the urban area (Offenberg and Baker, 1999; Bamford et al., 1999b). For this effort, we have estimated that 10% of the Bay's surface waters below the fall lines are influenced by urban deposition. As seen in Table 3.5, the overall Bay-wide atmospheric deposition loadings are quite sensitive to the fraction of the Bay that falls under the urban influence. Further meteorological analysis of mesoscale wind patterns are needed to refine the extent of the urban influence.

## **METHODOLOGY**

### *Wet Deposition*

In this report, the wet deposition fluxes of compound I ( $F_{i,wet}$ ,  $\mu\text{g}/\text{m}^2\text{-year}$ ) at a site are calculated as the product of volume-weighted mean chemical contaminant concentrations measured in precipitation ( $C_{i,ppt}$ ,  $\mu\text{g}/\text{m}^3$ ) and the corresponding precipitation amount ( $P$ ,  $\text{m}/\text{year}$ ):

$$F_{i,wet} = C_{i,ppt} \times P$$

In the available studies, weekly- or semi-weekly-integrated precipitation samples were analyzed. Annual wet deposition fluxes were calculated for each parameter at each site.

The 1994 TLRI used wet deposition data from the three rural Chesapeake Bay Atmospheric Deposition Study (CBADS) sites collected from June/July 1990 through the end of 1991 (Table 3.1). Measured parameters included elements (aluminum, iron, manganese, copper, chromium, lead, zinc, arsenic, and cadmium), polycyclic aromatic hydrocarbons, and polychlorinated biphenyl congeners. Annual wet deposition fluxes to the three CBADS sites were similar for most parameters and an areally-integrated annual load ( $\text{g}/\text{year}$ ) was calculated by multiplying the three site-specific fluxes by their representative water surface area below the fall-lines (CBP, 1994a). At the time of the 1994 TLRI, no consistent measurements of mercury or current-use agricultural chemicals in precipitation had been made, and no wet deposition loading estimates were made for these chemicals. Also, no information about wet deposition in Chesapeake Bay's urban areas was available for any chemical species. Therefore, the 1994 TLRI wet deposition load estimates represented regional background loadings.

The 1998 TLRI wet deposition loadings were calculated using exactly the same method used in the 1994 TLRI but with additional data (Table 3.1). An additional 21 months of CBADS wet deposition (bringing the total study period to June/July 1990 - September 1993) are incorporated into the refined wet deposition loadings. Mercury wet deposition loadings are now estimated using the studies of Mason et al. (1997a; 1997b). Wet deposition of agricultural chemicals is estimated from the work of Harman in the Patuxent River basin (Harman, 1996; Harman-Fetcho et al., 1998). While studies of wet deposition to urban areas are underway, only initial data are

### *Atmospheric Deposition Loadings*

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currently available to estimate the urban influence (Offenberg and Baker, 1999). Until other data are finalized, here we assume from the initial data that wet deposition fluxes of metals, PAHs, and PCBs are enriched two-, four, and ten-fold over regional background, respectively (Offenberg and Baker, 1999). Mason et al. (1997a) report that urban wet deposition of mercury is nearly twice the regional background.

#### *Dry Aerosol Deposition*

There is no uniformly accepted method to directly measure dry aerosol deposition fluxes to water surfaces. Numerous investigators have employed surrogate surfaces (e.g., Holsen et al., 1997 and references therein) and semi-empirical models (Zufall and Davidson, 1997 and references therein; Wu et al., 1992; Wu et al., 1994) to estimate dry aerosol deposition fluxes. In the Chesapeake Bay region, surrogate surface have not been routinely used to estimate fluxes, and the CBADS program estimated dry aerosol fluxes ( $F_{\text{dry}}$ ,  $\mu\text{g}/\text{m}^2\text{-year}$ ) as the product of measured ambient aerosol-associated contaminant concentrations ( $C_{\text{aero}}$ ,  $\mu\text{g}/\text{m}^3$ ) and a chemical-specific and meteorological-averaged dry deposition velocity ( $V_d$ ,  $\text{m}/\text{year}$ ):

$$F_{\text{dry}} = C_{\text{aero}} \times V_d$$

In the 1994 TLRI, measured aerosol-associated chemical contaminant concentrations were measured at regular intervals (weekly for elements and semi-weekly for PAHs and PCBs) from June/July 1990 until December 1991. Measured concentrations of elements were apportioned into ‘crustal’ and ‘non-crustal’ fractions using aluminum as the crustal tracer and typical crustal elemental abundances. The crustal and non-crustal fraction dry deposition velocities were estimated to be 0.26 and 1.4 cm/sec, respectively (Wu et al., 1992) and were assumed invariant among the three CBADS sites. Aerosol-bound organic contaminants were deposited with a velocity of 0.49 cm/sec (Leister and Baker, 1994). Since aerosol-bound polychlorinated biphenyls were not routinely detected in the CBADS samples, we used the Junge-Pankow model to estimate the sorbed PCB concentrations from the corresponding gas phase levels (Leister and Baker, 1994). Site-specific annual dry aerosol deposition fluxes were multiplied by the respective surface area of the Bay below the fall-lines to estimate Bay-wide loadings.

The 1998 TLRI dry aerosol deposition loadings were calculated in a similar manner as used in 1994. As with wet deposition, the longer CBADS data record was available for these revised calculations. Element deposition was calculated using the same dry deposition velocities as were used in 1994. However, further investigation of the size distributions of organic chemicals on ambient aerosols (Poster et al., 1995) has led us to reduce the organic contaminant deposition from 0.49 to 0.2 cm/sec. This lower value is likely more representative with the soot-like particles that transport most organic contaminants, and is consistent with the value used in the Great Lakes Integrated Atmospheric Deposition Network (IADN; Hoff et al., 1996).

### Gas Exchange

The application of two film transport models to calculate fluxes of semivolatile organic contaminants has recently been reviewed (Bidleman and M<sup>c</sup>Connell, 1995; Eisenreich et al., 1997). Instantaneous gas exchange rates across the air-water interface are modeled using the paired dissolved and gas phase measurements, temperature-corrected Henry's Law constants (Tateya et al., 1988; Bamford et al., 1999a), and estimates of mass transfer coefficients ( $K_{OLs}$ ) based on correlations with wind speed. To be consistent with previously reported PCB gas exchange rates in Green Bay (Achman et al., 1993) and Lake Michigan (Hornbuckle et al., 1995), we adopted the approach of those studies to estimate mass transfer coefficients and temperature-corrected Henry's Law constants (see Nelson et al., 1998 and references therein for details). Henry's Law constants of semivolatile organic contaminants are very sensitive to temperature, with  $H$  increasing approximately ten-fold with a 25°C increase in temperature (Tataya et al., 1988; Bamford et al., 1999a). We used the equation proposed by Tataya et al. (1988) to estimate temperature-corrected  $H$  values for PCBs:

$$\ln H_T = \ln H_{298} + 26.39 - \frac{7868}{T}$$

where  $H_T$  and  $H_{298}$  are the Henry's Law constants at temperature  $T$  and 298 K, respectively. Temperature-corrected PAH  $H$  values were calculated using the compound-specific enthalpies and entropies of phase change measured by Bamford et al. (1999a). The gas exchange mass transfer coefficient was estimated from correlations with wind speed (as a surrogate measure of surface turbulence) and molecular diffusivity in air and water, as described in Hornbuckle et al. (1995) and detailed in Nelson et al. (1998).

No gas exchange fluxes were included in the 1994 TLRI. Data from several recent publications were used to estimate gas exchange fluxes in the 1998 TLRI. Nelson et al. (1998) and M<sup>c</sup>Connell et al. (1997) measured gas exchange fluxes of organic contaminants and pesticides, respectively, during four Bay-wide cruises in 1993. Gustafson and Dickhut (1997) measured PAH gas exchange rates in the southern Chesapeake Bay. Harman (1996) estimated gas exchange rates of current-use agrichemicals in the Patuxent River in 1995. More recently, Bamford et al. (1999b) estimated exchange fluxes of PAHs across the air-water interface of the urban Patapsco River during three intensive studies in June 1996 and February and July 1997. Here we rely primarily on the Nelson et al. (1998) and Harman (1996) studies to estimate regional background gas exchange rates of PCBs, PAHs, and agrichemicals, and the work of Bamford et al. (1999b) for urban-enhanced gas exchange rates. As seen in Table 3.3, gas exchange rates of PAHs in the urban Patapsco River system are much different than those in the open Bay. Many PAHs, including fluorene, anthracene, fluoranthene, and pyrene volatilize from

surface waters in the urban area, as elevated dissolved concentrations drive the diffusional gradient. In contrast, the net flux of phenanthrene is into the urban surface water (Bamford et al., 1999b) at rates similar to those observed in the mainstem Chesapeake (Nelson et al., 1998). Comparable phenanthrene exchange rates in the urban and regional waters do not imply similar concentration of this PAH. Rather, both the urban atmosphere and surface water are enriched in phenanthrene, resulting in a comparable gradient as seen in the mainstem Bay waters.

## **UNCERTAINTY**

### *Error Analysis in Wet Deposition Calculations*

Sources of random error in wet deposition loading estimates include the measurement errors associated with quantifying chemical concentration in precipitation and the rainfall amount. Here we adopt the error analysis of the CBADS program, and assign propagated uncertainties to the wet metals and organics fluxes of  $\pm 10\%$  and  $\pm 20\%$ , respectively. Another potentially larger but unquantified source of uncertainty in wet deposition loadings results from the spatial interpolation among the few regional and single urban deposition sites. This is especially problematic when applying the 'urban influence' to a specific area. However, any spatial variation in the regional background appears to be relatively small on an annual basis, perhaps a factor of two. Recently, wet deposition of metals has been measured to the Bear Branch watershed in Thurmont, Maryland (Church et al., 1998). The Bear Branch metals annual wet deposition fluxes are equal to or slightly greater than those used in this study (Bear Branch receives higher annual average precipitation than the Bay-wide average). The similarities between the wet deposition fluxes estimated here and the independently determined fluxes at Bear Branch suggest that the uncertainties of extrapolation of the regional background wet deposition fluxes are not large.

### *Error Analysis in Dry Aerosol Deposition Calculations*

The largest uncertainty in the dry aerosol deposition estimates results from our poor understanding of the chemical-specific dry deposition velocities. Dry deposition strongly depends upon the over-water wind speed and the size distribution of the aerosol particles. Both are known to vary greatly spatially and temporally. However, integrating dry deposition fluxes over time to estimate annual loadings tends to dampen out this variability. Nonetheless, the estimated dry aerosol deposition loadings here are likely accurate to within a factor of 2-3.

### *Error Analysis in Gas Exchange Calculations*

Uncertainty in calculated instantaneous gas exchange fluxes result from systematic and random measurement errors, systematic errors in the values of  $H$  values, and uncertainties due to the mass transfer coefficient calculations. To assess the relative magnitude of random errors in the instantaneous gas exchange flux calculations, propagation of error analysis was performed:

where F is the instantaneous gas exchange flux resulting from the difference in dissolved ( $C_d$ )

$$\sigma^2(F) = \left(\frac{\delta F}{\delta K_{OL}}\right)^2 (\sigma K_{OL})^2 + \left(\frac{\delta F}{\delta C_d}\right)^2 (\sigma C_d)^2 + \left(\frac{\delta F}{\delta C_a}\right)^2 (\sigma C_a)^2 + \left(\frac{\delta F}{\delta H}\right)^2 (\sigma H)^2$$

and gas phase ( $C_a$ ) concentrations, accounting for H. Total propagated variance [ $\sigma^2(F)$ ] is the linear combination of the weighted contribution of the variances ( $\sigma^2$ ) of the mass transfer coefficient, H, and measured concentrations. The  $\sigma H$  term is assumed equal to zero because H is a constant and under any singular condition there is no random error (deviations in estimated H values from their true values are systematic, not random errors). To estimate the overall random error in the flux calculation, measurement precision was estimated to be 10%, based upon repeated sample injections. While the total analytical uncertainty is likely greater than 10%, the overall propagated error in the flux is relatively insensitive to the error in the concentration term (see below). Uncertainty in  $K_{OL}$  was determined by propagating random errors in the air- and water-side transfer velocities, which here we assume to be 40% based on inspection of  $k_w$  versus wind speed plots in Wanninkhof et al. (1990). Using these estimated errors, we calculate the overall random error of a typical instantaneous gas exchange flux as ca. 40%, with a majority of the uncertainty arising from  $K_{OL}$ . As a specific example, the flux of fluorene into Site 1 on 8 March 1993 is  $413 \pm 139$  ng/m<sup>2</sup>-day (Nelson et al., 1998), with 88% of the random error due to uncertainty in  $K_{OL}$ , and 11% and <1% of the error due to uncertainty in the measured gas phase and dissolved concentrations, respectively. Propagation of error demonstrates that the significant improvements in estimating gas exchange fluxes will require better understanding of the mass transfer process itself rather than improved characterization of the concentration gradients.

Significant sources of possible systematic errors include improper quantification of the concentration gradient due to including colloidally bound contaminants in the ‘dissolved’ phase measurement, underestimations of the wind effects on  $K_{OL}$ , and using inaccurate values of H. Henry’s Law constants of organic compounds increase with salinity due to an increase in the aqueous activity coefficient. Based on their review of studies that compared H values measured in freshwater and seawater, Staudinger and Roberts (1996) concluded that these constants increase at most six-fold but more commonly two- to four-fold in seawater, with the effect of salinity more pronounced for larger molecules. The salinity of the Chesapeake Bay surface waters ranged from 0‰ in the north to 27‰ in the south during this study, suggesting that H values may have increased 2-3 fold from north to south. Due to the lack of compound-specific H-salinity relationships, we could not make this correction in our calculations.

## LOADING ESTIMATES

Bay-wide atmospheric deposition loading estimates are summarized in Table 3.4. Here



we divide the Bay's surface waters below the fall-lines into sub-regions to be consistent with the 1994 TLRI. Bay-wide regional background fluxes were calculated by linear averaging all available data from non-urban sites. Urban fluxes were estimated as multiples of the regional background fluxes as described above and detailed in Table 3.3. Bay-wide loads equal the average annual fluxes multiplied by the surface area of each sub-region, with the total below fall-line area equal to  $1.15 \times 10^{10} \text{ m}^2$ .

## **CORRELATION WITH 1994 TOXICS LOADING AND RELEASE INVENTORY**

Estimates of total annual, Bay-wide atmospheric deposition loads of metals are very similar between the 1994 and 1998 TLRIs, with arsenic, cadmium, chromium, copper, lead and zinc all within  $\pm 20\%$  (Table 3.6). These differences are well within the uncertainty of the loadings estimates. The agreement between the two reports reflects a common source of the wet deposition data (CBADS) and a consistent modeling of the dry aerosol deposition flux. Note that we have assumed a conservative two-fold enhanced metals deposition in urban areas. If studies currently underway document a larger enrichment, the metals loadings will increase from the 1998 TLRI values.

Estimates of organic contaminant deposition loadings are dramatically different between the 1994 and 1998 TLRIs (Table 3.6), reflecting the large number of recent studies. The two main differences between the two reports is the inclusion of gas exchange fluxes in 1998 and the reduction of the dry aerosol deposition velocity from 0.49 to 0.2 cm/sec. The estimated fluoranthene loading was similar between the two reports (635 and 595 kg/year), as including net gas exchange was offset by lower aerosol deposition estimates. Net gas exchange flux represents 90% of the total fluoranthene load from the atmosphere. In contrast, loadings estimates of benz[a]anthracene, chrysene, and benzo[a]pyrene all decrease by 70-80% between the two inventories. These decreases result from the reduction in dry aerosol deposition attributed to the lower deposition velocity and from the volatilization of these PAHs from surface waters adjacent to urban areas. The somewhat paradoxical result of lower atmospheric loading estimates when urban influences are considered is explained by the increased contaminant inventory in the water column (resulting in enhanced volatilization).

The largest difference between the 1994 and 1998 estimates is for total polychlorinated biphenyls (t-PCBs). The 1994 estimate only considered wet and dry aerosol deposition, both advective processes resulting in net deposition. The 1998 estimate not only updates these estimates, but now considers the role of gas exchange. As shown by Nelson et al. (1998), the Chesapeake Bay surface waters are supersaturated with dissolved PCBs relative to the overlying atmosphere, resulting in large volatilization fluxes. Our best estimates are that the Chesapeake Bay is currently out-gassing 400 kg PCB/year, which is more than an order of magnitude more than the wet and dry aerosol deposition combined. In fact, volatilization appears to be the dominant loss process for PCBs from the estuary, and may control the overall removal of PCBs (and perhaps other organochlorines) from this system.

## RECOMMENDATIONS

In order to further improve upon these estimates of atmospheric deposition loadings, the following information is required:

- ▶ Improved Estimates of Atmospheric Deposition to Water Surfaces
  - Measure meteorological and chemical parameters at an array of stationary sites located in the mainstem of the Chesapeake Bay in order to get true over-water measurements.
  - Establish and maintain atmospheric deposition monitoring sites along gradients within the major urban areas of the Bay (Baltimore, Washington, Norfolk).
  - Conduct intensive sampling campaigns in urban and agricultural areas during contrasting wet and dry periods.
  - Continue to monitor atmospheric deposition at one or more of the regional CBADS sites to document longer term trends.
  - Characterize the spatial and temporal distribution of atmospheric stability and air-water interface turbulence for improved gas exchange and dry aerosol deposition estimates.
  - Measure chemical-specific aerosol size distributions in urban and rural atmospheres adjacent to the Bay to better characterize dry aerosol deposition. This might be done in collaboration with USEPA's PM<sub>2.5</sub> monitoring programs.
  - Refine regional scale atmospheric transport models for use as 'interpolators' of measured deposition fluxes.
- ▶ Improved estimates of atmospheric deposition to the watershed. Neither the 1994 or 1998 TLRI attempted to estimate atmospheric deposition loadings to the watershed of the Bay. Determining the atmospheric component of the 'fall-line loads' of contaminants remains an important unresolved question, and data should be obtained so that the next TLRI can include initial estimates.
  - Establish and maintain at least one monitoring station in each representative watershed (agricultural, forested, urban) to measure the deposition of specific chemical contaminants.
  - Conduct intensive studies at the watershed scale to determine retention of deposited atmospheric chemicals by watersheds of differing land uses (similar to the Bear Branch study; Church et al., 1998).
  - Conduct atmospheric deposition studies in concert with 'fall-lines' monitoring studies in order to estimate the atmospheric component of the fall-line chemical contaminant loads.
  - Investigate contaminant inventories in the soils and vegetation of the Bay's watershed in order to estimate the 'storage' of atmospherically-derived chemicals.
  - Develop watershed-scale models of atmospheric transport, deposition, and retention, perhaps building on the CBPO nutrient watershed model.

Table 3.1. Data Sources for 1998 Atmospheric Deposition Estimates.

<b>Chemical</b>	<b>Dates</b>	<b>Location</b>	<b>Wet</b>	<b>Dry Aerosol</b>	<b>Gas Exchange</b>	<b>Reference</b>
PAHs	July 1990 - Sept. 1993	Wye, Elms, Haven Beach	X	X		Baker et al., 1997
PCBs	July 1990 - Sept. 1993	Wye, Elms, Haven Beach	X	X		Baker et al., 1997
Metals	July 1990 - Sept. 1993	Wye, Elms, Haven Beach	X	X		Baker et al., 1997
PAHs	March, April, June, and September 1993	Mainstem Chesapeake			X	Nelson et al., 1998
PAHs	August 1995, June 1996; February and July 1997	Patapsco River and northern Chesapeake Bay			X	Bamford et al., 1999b
PCBs	March, April, June, and September 1993	Mainstem Chesapeake			X	Nelson et al., 1998
Chloropyrifos	March, April, June, and September 1993	Mainstem Chesapeake	X	X	X	McConnell et al., 1997
PAHs	Jan. 1994 - June 1995	Southern - Western Shore			X	Gustafson and Dickhut, 1997
Mercury	Sept. 1995 - Sept. 1996	Hart-Miller Island, Stillpond, Kent County MD	X			Mason et al., 1997
Mercury	May 1995 - Present	Chesapeake Biological Laboratory, Solomons	X			
Agrochemicals	April - June 1995	Patuxent River	X		X	Harman, 1996

***Atmospheric Deposition Loadings***

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Table 3.2. Surface Water Segments Below the Fall Lines Used to Calculate Atmospheric Deposition Loads (From 1994 Chesapeake Bay Basin Toxics Loading and Release Inventory).

<b>Basin</b>	<b>Surface Water Area (10<sup>6</sup> m<sup>2</sup>)</b>	<b>Percent Urban</b>
Mainstem Bay	7466	10%
Susquehanna	14	10%
West Chesapeake	435	10%
Patuxent	278	10%
Potomac	1216	10%
Rappahannock	452	10%
York	262	10%
James	681	10%
Eastern Shore	694	10%
TOTAL	11498	

Table 3.3. Average Annual Atmospheric Deposition Fluxes ( $\mu\text{g}/\text{m}^2\text{-year}$ ) to the Chesapeake Bay.

	Wet Deposition <sup>(1)</sup>		Dry Aerosol Deposition <sup>(2)</sup>		Gas Exchange <sup>(3)</sup>		Total Deposition	
	Regional	Urban	Regional	Urban	Regional	Urban	Regional	Urban
Aluminum	11,500	23,000	107,000	214,000	none	none	118,500	237,000
Arsenic	54	108	100	200	none	none	154	308
Cadmium	62	124	26	52	none	none	88	176
Chromium	100	200	200	400	none	none	300	600
Copper	370	740	340	680	none	none	710	1,420
Iron	10,500	21,000	58,500	117,000	none	none	69,000	138,000
Manganese	1,050	2,100	1,200	2,400	none	none	2,250	4,500
Nickel	330	660	570	1,140	none	none	900	1,800
Lead	450	900	710	1,420	none	none	1,160	2,320
Selenium	110	220	260	520	none	none	370	740
Zinc	1,500	3,000	2,100	4,200	none	none	3,600	7,200
Fluorene	1.2	4.8	0.3	1.4	33	-200	35	-194
Phenanthrene	4.8	19.2	2.7	10.8	250	220	258	250
Anthracene	0.5	2.1	0.2	0.8	11	-36	12	-33
Fluoranthene	5.1	20.4	3.1	12.4	59	-120	67	-87
Pyrene	5.0	20.0	2.9	11.6	31	-130	39	-98
Benz[a]anthracene	0.9	3.6	1.0	3.8	-0	ca.0	1	7
Chrysene	2.2	8.8	2.4	9.6	3	-2	7	16
Benzo[b]fluoranthene	2.6	10.4	2.7	10.8	ca.0	ca.0	5	21
Benzo[k]fluoranthene	1.6	6.4	1.8	7.2	ca.0	ca.0	3	14
Benzo[e]pyrene	2.0	8.0	1.9	7.6	ca.0	ca.0	4	19
Benzo[a]pyrene	1.3	5.2	1.0	4.0	ca.0	ca.0	2	9
Indeno[123cd]perylene	1.5	6.0	2.0	8.0	ca.0	ca.0	4	14
Dibenz[a,h]anthracene	0.5	2.1	0.4	1.7	ca.0	ca.0	1	4
Benzo[ghi]perylene	1.4	5.6	1.5	6.0	ca.0	ca.0	3	12
Total PCBs	0.8	8.3	0.8	8.0	-35	-35	-33	16
Mercury <sup>(4)</sup>	13	24	3	5	-10	-10	6	29
Chlorpyrifos	2.80	2.80	0.13	0.13	-0.48	-0.48	2.5	2.5
Metolachlor	40.3	40.3	1.90	1.90	0.27	0.27	42.5	4215

### **3-13**

#### Footnote

- a) No urban metal deposition data are currently available; assume urban =2x regional as conservative estimate.
- b) Dry aerosol deposition fluxes calculated from measured ambient aerosol concentrations, using 0.2 cm/sec deposition velocity for organics, 0.26 cm/sec for non-crustal metals, and 1.4 cm/sec for crustal metals).
- c) PCB dry aerosol deposition flux calculated from the measured gaseous PCB concentrations and the Junge-Pankow sorption model (see Baker et al., 1997).
- d) Urban wet and dry aerosol deposition of organics based on Offenberg and Baker, 1999; assuming 4x and 10x increase in PAH and PCB wet deposition, respectively, and 4x and 10x increase in PCB and PAH concentrations in the urban atmosphere, respectively.

#### References

- (1) Metals in wet and dry aerosol deposition: Baker et al., 1997 (average of data from 3 CBADS sites June 1990 - September 1993).
- (2) Organics in wet and dry aerosol deposition: Baker et al., 1997 (average of data from 3 CBADS sites June 1990 - September 1993. NB: organics deposition velocity changed from 0.49 to 0.2 cm/sec to reflect refined estimates (see Wu et al., 1992).
- (3) Organics gas exchange : Nelson et al., 1998, average of 7 mainstem sites during 4 cruises in 1993; Bamford et al., 1999; average of several consecutive daily transects in the Patapsco River system during June 1996, and February and July 1997.
- (4) Mercury: Mason et al., 1997, urban data from Hart-Miller Island; regional from CBL).

Table 3.4a. Wet Deposition Loads (kg/year) to the Chesapeake Bay Below the Fall-Lines.

	Mainstem	Susquehanna	West Chesapeake	Patuxent	Potomac	Rappahannock	York	James	Eastern Shore	Total
Surface Area (m <sup>2</sup> )	7.5E+09	1.4E+07	4.4E+08	2.8E+08	1.2E+09	4.5E+08	6.8E+08	6.8E+08	6.9E+08	1.1E+010
Percent Urban	10%	10%	10%	10%	10%	10%	10%	10%	10%	
Aluminum	94,400	180	5,500	3,500	15,400	5,700	3,300	8,600	8,800	145,400
Arsenic	400	1	26	17	72	27	16	40	41	700
Cadmium	500	1	30	19	83	31	18	46	47	800
Chromium	800	2	48	31	130	50	29	75	76	1,300
Copper	3,000	6	180	100	500	180	100	300	300	4,700
Iron	86,200	160	5,000	3,200	14,000	5,200	3,000	7,900	8,000	132,800
Manganese	8,600	16	500	300	1,400	520	300	800	800	13,000
Nickel	2,710	5	160	100	440	160	95	250	250	4,200
Lead	3,700	7	200	140	600	200	130	300	3300	5,700
Selenium	900	2	53	34	150	55	32	82	84	1,4000
Zinc	12,300	23	700	460	2,000	700	430	1,100	1,100	19,000
Fluorene	11.6	0.02	0.7	0.4	1.9	0.7	0.4	1.1	1.1	17.9
Phenanthrene	46.6	0.09	2.7	1.7	7.6	2.8	1.6	4.2	4.3	71.7
Anthracene	5.1	0.01	0.3	0.2	0.8	0.3	0.2	0.5	0.5	7.9
Fluoranthene	49.5	0.09	2.9	1.8	8.1	3.0	1.7	4.5	4.6	76.2
Pyrene	48.5	0.09	2.8	1.8	7.9	2.9	1.7	4.4	4.5	74.7
Benz[a]anthracene	8.7	0.02	0.5	0.3	1.4	0.5	0.3	0.8	0.8	13.5
Chrysene	21.4	0.04	1.2	0.8	3.5	1.3	0.7	1.9	2.0	32.9
Benzo[b]fluoranthene	25.2	0.05	1.5	0.9	4.1	1.5	0.9	2.3	2.3	38.9
Benzo[k]fluoranthene	15.5	0.03	0.9	0.6	2.5	0.9	0.5	1.4	1.4	23.9
Benzo[e]pyrene	19.4	0.04	1.1	0.7	3.2	1.2	0.7	1.8	1.8	29.9
Benzo[a]pyrene	12.6	0.02	0.7	0.5	2.1	0.8	0.4	1.2	1.2	19.4
Indeno[123cd]perylene	14.6	0.03	0.8	0.5	2.4	0.9	0.5	1.3	1.4	22.4
Dibenz[a,h]anthracene	5.1	0.01	0.3	0.2	0.8	0.3	0.2	0.5	0.5	7.9
Benzo[ghi]perylene	13.6	0.03	0.8	0.5	2.2	0.8	0.5	1.2	1.3	20.9
Total PCBs	11.8	0.02	0.7	0.4	1.9	0.7	0.4	1.1	1.1.	18.1
Mercury	105.3	0.20	6.1	3.9	17.1	6.4	3.7	9.6	9.8	162.1
Chloropyrifos	20.9	0.04	1.2	0.8	3.4	1.3	0.7	1.9	1.9	32.2
Metolachlor	300.9	0.56	17.5	11.2	49.0	18.2	10.6	27.4	28.0	463.4

Table 3.4b. Dry Aerosol Deposition Loads (kg/year) to the Chesapeake Bay Below the Fall-Lines.

	Mainstem	Susquehanna	West Chesapeake	Patuxent	Potomac	Rappahannock	York	James	Eastern Shore	Total
Surface Area (m <sup>2</sup> )	7.5E+09	1.4E+07	4.4EE+08	2.8E+08	1.2E+09	4.5E+08	6.8E+08	6.8E+08	6.9E+08	1.1E+010
Percent Urban	10%	10%	10%	10%	10%	10%	10%	10%	10%	
Aluminum	878,700	1,600	51,200	32,700	143,100	53,200	30,800	80,200	81,700	1,350,000
Arsenic	800	2	48	31	130	50	29	75	76	1,300
Cadmium	200	0	12	8	35	13	7	19	20	330
Chromium	1,600	3	96	61	270	99	58	150	150	2,500
Copper	2,800	5	160	100	460	170	98	260	260	4,300
Iron	480,400	900	28,000	17,900	78,300	29,100	16,860	43,800	44,700	740,000
Manganese	9,900	18	600	370	1,600	600	350	900	900	15,200
Nickel	4,700	9	300	170	770	280	160	420	430	7,200
Lead	5,800	11	300	200	950	350	200	530	540	8,900
Selenium	2,100	4	100	80	350	130	75	200	200	3,300
Zinc	17,200	32	1,000	640	2,800	1,000	600	1,600	1,600	26,600
Fluorene	3.3	0.01	0.2	0.1	0.5	0.2	0.1	0.3	0.3	5.1
Phenanthrene	26.2	0.05	1.5	1.0	4.3	1.6	0.9	2.4	2.4	40.4
Anthracene	1.9	0.00	0.1	0.1	0.3	0.1	0.1	0.2	0.2	3.0
Fluoranthene	30.1	0.06	1.8	1.1	4.9	1.8	1.1	2.7	2.8	46.3
Pyrene	28.1	0.05	1.6	1.0	4.6	1.7	1.0	2.6	2.6	43.3
Benz[a]anthracene	9.2	0.02	0.5	0.3	1.5	0.6	0.3	0.8	0.9	14.2
Chrysene	23.3	0.04	1.4	0.9	3.8	1.4	0.8	2.1	2.2	35.9
Benzo[b]fluoranthene	26.2	0.05	1.5	1.0	4.3	1.6	0.9	2.4	2.4	40.4
Benzo[k]fluoranthene	17.5	0.03	1.0	0.7	2.8	1.1	0.6	1.6	1.6	26.9
Benzo[e]pyrene	18.4	0.03	1.1	0.7	3.0	1.1	0.6	1.7	1.7	28.4
Benzo[a]pyrene	9.7	0.02	0.6	0.4	1.6	0.6	0.3	0.9	0.9	14.9
Indeno[123cd]perylene	19.4	0.04	1.1	0.7	3.2	1.2	0.7	1.8	1.8	29.9
Dibenz[a,h]anthracene	4.1	0.01	0.2	0.2	0.7	0.2	0.1	0.4	0.4	6.3
Benzo[ghi]perylene	14.6	0.03	0.8	0.5	2.4	0.9	0.5	1.3	1.4	22.4
Total PCBs	11.3	0.02	0.7	0.4	1.8	0.7	0.4	1.0	1.1	17.5 ]
Mercury	21.1	0.04	1.2	0.8	3.4	1.3	0.7	1.9	2.0	32.4
Chloropyrifos	1.0	0.002	0.06	0.04	0.16	0.06	0.03	0.09	0.09	1.5
Metolachlor	14.2	0.027	0.83	0.53	2.31	0.86	0.50	1.29	1.32	21.8



Table 3.4c. Net Gas Exchange Deposition Loads (kg/year) to the Chesapeake Bay Below the Fall-Lines (negative=atmosphere is net sink).

	Mainstem	Susquehanna	West Chesapeake	Patuxent	Potomac	Rappahannock	York	James	Eastern Shore	Total
Surface Area (m <sup>2</sup> )	7.5E+009	1.4E+007	4.4EE+008	2.8E+008	1.2E+009	4.5E+008	6.8E+008	6.8E+008	6.9E+008	1.1E+010
Percent Urban	10%	10%	10%	10%	10%	10%	10%	10%	10%	
Aluminum	0	0	0	0	0	0	0	0	0	0
Arsenic	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0
Copper	0	0	0	0	0	0	0	0	0	0
Iron	0	0	0	0	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0
Selenium	0	0	0	0	0	0	0	0	0	0
Zinc	0	0	0	0	0	0	0	0	0	0
Fluorene	72	0.1	4	3	12	4	3	7	7	100
Phenanthrene	1,800	3.5	110	69	300	100	65	170	180	2,800
Anthracene	47	0.1	3	2	8	3	2	4	4	72
Fluoranthene	307	0.6	18	11	50	19	11	28	29	500
Pyrene	100	0.2	6	4	18	7	4	10	10	180
Benz[a]anthracene	-3	-0.0	-0	-1	-0	09	-0	-0	-0	-4
Chrysene	15	0.0	1	1	2	1	1	1	1	24
Benzo[b]fluoranthene	0	0.0	0	0	0	0	0	0	0	0
Benzo[k]fluoranthene	0	0.0	0	0	0	0	0	0	0	0
Benzo[e]pyrene	0	0.0	0	0	0	0	0	0	0	0
Benzo[a]pyrene	0	0.0	0	0	0	0	0	0	0	0
Indeno[123cd]perylene	0	0.0	0	0	0	0	0	0	0	0
Dibenz[a,h]anthracene	0	0.0	0	0	0	0	0	0	0	0
Benzo[ghi]perylene	0	0.0	0	0	0	0	0	0	0	0
Total PCBs	-261	-0.5	-15	-10	-43	-16	-9	-24	-24	-402
Mercury	-75	-0.1	-4	-3	-12	-5	-3	-7	-7	-115
Chloropyrifos	-3.6	-0.01	-0.21	-0.13	-0.58	-0.22	-0.13	-0.33	-0.33	-5.5
Metolachlor	2.0	0.00	0.12	0.08	0.33	0.12	0.07	0.18	0.19	3.1

Table 3.4d. Total Atmospheric Deposition Loads (kg/year) to the Chesapeake Bay Below the Fall-Lines.

	Mainstem	Susquehanna	West Chesapeake	Patuxent	Potomac	Rappahannock	York	James	Eastern Shore	Total
Surface Area (m <sup>2</sup> )	7.5E+09	1.4E+07	4.4EE+08	2.8E+08	1.2E+09	4.5E+08	6.8E+08	6.8E+08	6.9E+08	1.1E+010
Percent Urban	10%	10%	10%	10%	10%	10%	10%	10%	10%	
Aluminum	973,200	1,800	56,700	36,200	158,500	58,900	34,200	88,800	90,500	1,499,000
Arsenic	1,300	2	74	47	200	77	44	110	100	2,000
Cadmium	700	1	42	27	100	44	25	66	67	1,100
Chromium	2,500	5	140	92	400	150	86	200	200	4,800
Copper	5,900	11	340	200	950	350	200	500	500	9,000
Iron	566,700	1,100	33,000	21,100	92,300	34,300	19,900	51,700	52,700	873,000
Manganese	18,500	35	1,080	700	3,010	1,100	650	1,700	1,800	28,500
Nickel	7,400	14	430	300	1,200	450	300	700	700	11,400
Lead	9,500	18	600	400	1,600	600	300	900	900	14,700
Selenium	3,000	6	200	110	500	200	100	3000	300	4,700
Zinc	29,600	55	1,800	1,100	4,800	1,800	1,000	2,700	2,700	45,500
Fluorene	87.4	0.16	5.1	3.3	14.2	5.3	3.1	8.0	8.1	135
Phenanthrene	1,916.9	3.59	111.7	71.4	312.2	116.1	67.3	174.8	178.2	2950
Anthracene	54.1	0.10	3.2	2.0	8.8	3.3	1.9	4.9	5.0	83
Fluoranthene	386.4	0.72	22.5	14.4	62.9	23.4	13.6	35.2	35.9	595
Pyrene	187.9	0.35	10.9	7.0	30.6	11.4	6.6	17.1	17.5	289
Benz[a]anthracene	15.3	0.03	0.9	0.6	2.5	0.9	0.5	1.4	1.4	24
Chrysene	60.0	0.11	3.5	2.2	9.8	3.6	2.1	5.5	5.6	92
Benzo[b]fluoranthene	51.4	0.10	3.0	1.9	8.4	3.1	1.8	4.7	4.8	79
Benzo[k]fluoranthene	33.0	0.06	1.9	1.2	5.4	2.0	1.2	3.0	3.1	51
Benzo[e]pyrene	37.9	0.07	2.2	1.4	6.2	2.3	1.3	3.5	3.5	58
Benzo[a]pyrene	22.3	0.04	1.3	0.8	3.6	1.4	0.8	2.0	2.1	34
Indeno[123cd]perylene	34.0	0.06	2.0	1.3	5.5	2.1	1.2	3.1	3.2	52
Dibenz[a,h]anthracene	9.2	0.02	0.5	0.3	1.5	0.6	0.3	0.8	0.9	14
Benzo[ghi]perylene	28.1	0.05	1.6	1.0	4.6	1.7	1.0	2.6	2.6	43
Total PCBs	-238.2	-0.45	-13.9	-8.9	-38.8	-14.4	-8.4	-21.7	-22.1	-367
Mercury	51.7	0.10	3.0	1.9	8.4	3.1	1.8	4.7	4.8	80
Chloropyrifos	18	0.0	1.1	0.7	3.0	1.1	0.6	1.7	1.7	28
Metolachlor	317	0.6	18.5	11.8	51.6	19.2	11.1	28.9	29.5	490

Table 3.5. Influence of Urban Areas on Atmospheric Deposition Loadings (kg/y) to the Chesapeake Bay.

	<b>Percent Urban</b>				
	<b>0%</b>	<b>5%</b>	<b>10%</b>	<b>20%</b>	<b>30%</b>
Aluminum	1,363,000	1,430,000	1,499,000	1,635,000	1,770,000
Arsenic	1,800	1,900	2,000	2,100	2,300
Cadmium	1,000	1,100	1,100	1,200	1,300
Chromium	3,400	3,600	3,800	4,100	4,500
Copper	8,200	8,600	9,000	9,800	10,600
Iron	793,000	833,000	873,000	952,000	1,030,000
Manganese	25,900	27,200	28,500	31,000	33,700
Nickel	10,300	10,900	11,400	12,400	13,400
Lead	13,300	14,000	14,700	16,000	17,300
Selenium	4,300	4,500	4,700	5,100	5,500
Zinc	41,400	43,500	45,500	49,700	53,800
Fluorene	400	300	100	-128	-391
Phenanthrene	3000	3000	3000	3000	3000
Anthracene	100	100	83	32	-20
Fluoranthene	800	700	600	400	240
Pyrene	400	400	300	100	-26
Benz[a]anthracene	17	20	24	30	37
Chrysene	82	87	92	100	114
Benzo[b]fluoranthene	61	70	79	98	116
Benzo[k]fluoranthene	39	45	51	63	74
Benzo[e]pyrene	45	52	58	72	85
Benzo[a]pyrene	26	30	34	42	50
Indeno[123cd]perylene	40	46	52	64	76
Dibenz[a,h]anthracene	11	13	14	17	21
Benzo[ghi]perylene	33	38	43	53	63
Total PCBs	-384	-375	-367	-350	-333
Mercury	64	72	80	95	110
Chloropyrifos	28	28	28	28	28
Metolachlor	488	488	488	488	488

Table 3.6. Comparison of 1994 and 1998 TLRI Atmospheric Deposition Loadings.

	1994	1998	% Difference	Main Cause of Difference
Arsenic	1,800	2,000	13%	Difference less than uncertainty in loading estimate
Cadmium	1,200	1,100	-9%	Difference less than uncertainty in loading estimate
Chromium	3,400	3,800	12%	Difference less than uncertainty in loading estimate
Copper	10,900	9,000	-18%	Difference less than uncertainty in loading estimate
Lead	14,500	14,700	1%	Difference less than uncertainty in loading estimate
Zinc	41,300	45,500	10%	Difference less than uncertainty in loading estimate
Fluoranthene	600	600	-6%	Difference less than uncertainty in loading estimate
Benz[a]anthracene	100	24	-83%	Decreased deposition velocity; Including gas exchange
Chrysene	300	92	-71%	Decreased deposition velocity; Including gas exchange
Benzo[a]pyrene	100	34	-73%	Decreased deposition velocity; Including gas exchange
Total PCBs	59	-367	-722%	Including gas exchange

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## CHAPTER 4 - Shipping and Boating Loadings

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### INTRODUCTION

The tidal waters of the Bay and its tributaries support a wide variety of commercial, recreational and military activities. Toxic substances are associated with these activities as cargo; consumable products such as fuel, lubricants, paints, antifreeze; and by-products such as contaminated bilge water, sewage, and dredge spoil. These materials can reach the tidal waters by accidental and/or intentional discharges from water craft, land based facilities adjacent to the water, and aircraft accidents. This section provides analyses and summary of the reported spills of this nature.

The intention of this analysis is to update the material for the 1980 to 1989 period presented in the Shipping and Boating Loadings chapter of the 1994 edition of the *Chesapeake Bay Basinwide Toxics Loading and Release Inventory* (1994 TLRI). This work provides spill loadings below the fall line in order to supplement the toxics loading information developed from the fall line monitoring program. Upstream spills may be accounted for in monitoring at the fall line. The greatest quantities of materials spilled during the 1990 to 1996 period were of petroleum based products: fuels, lubricants, and asphalt. These products are on and near the Bay in large quantities as cargo and as consumables. Information with respect to materials and quantities spilled is collected and maintained by several agencies, notably the US Coast Guard and the US Environmental Protection Agency.

### TEMPORAL AND SPATIAL COVERAGE

Spill data for calendar years 1990 through 1996 were obtained from several information management agencies. This period extends the 1980 to 1989 period covered in the 1994 edition of the TLRI for shipping and boating loadings. The data were initially screened for location to include the tidal waters of the Bay and adjacent land by state, county, and city. The data for the land based spills were further refined to include only those which were from stationary facilities or mobile sources to tidal waters (below the fall line).

### METHODOLOGY

The loads of toxic materials included in this section of the inventory were derived from data provided by the Emergency Response Notification System (ERNS) which is managed by the US EPA, and the US Coast Guard Marine Safety Information System (MSIS). The ERNS

maintains a computer database containing information on release notifications of oil and hazardous substances that have occurred throughout the United States and have been reported to the National Response Center, the ten US EPA Regions, or the US Coast Guard. Some data on file with the US Coast Guard appeared not to be included in the ERNS database; therefore, similar information requests were made to both organizations for completeness. These data include spills associated with cargo and by-products from commercial, recreational and military activities.

Data were also requested and received from the relevant regional offices of the Virginia Department of Environmental Quality, Virginia Department of Emergency Services, and Maryland Department of the Environment. The data from these agencies were examined and found to lack key information for this analysis, or were not compatible with each other or the ERNS or MSIS data; therefore, they are not included in the inventory. However, there is likely considerable overlap between the incidents contained in the state agency databases and those in the ERNS and MSIS due to common reporting requirements.

The data requests to the data management agencies sought information concerning: material spilled, quantity of spill, quantity recovered, units of measurement, restricted location to tidal counties and independent cities around the Chesapeake Bay, whether to water or not, address of spill, whether from a water vessel or land based facility or aircraft accident, date restricted to 1990 through 1996, time of day, and notes or comments. A list of Chesapeake Bay tidal counties and independent cities was provided as part of the data request. The raw data which were received consisted of 5,647 records from ENRS and 4,109 records from MSIS containing various information parameters for each spill incident. The major analytical tasks included developing specific and consistent location, material, and quantity information.

Locational analysis was by far the most difficult task. The objective was to provide information on only those spills which were directly to tidal waters (or indirectly by runoff from adjacent land based facilities). No parameters existed in the data sets which would allow such sorting entirely by computer methods. The location information available from the data management agencies included: state, and/or county, and/or city, and/or street address, and/or receiving water body. The data were sorted successively by each of the stated classes of location information, and those records that were not potentially in the tidal Chesapeake region were discarded. The information provided for some spills was insufficient to determine if the spill directly reached tidal waters, and those record were discarded. The last locational task was to assign a Chesapeake Bay basin watershed designation individually to each record; however, this task was performed only after all other data sorting and reduction tasks were completed.

The ERNS and MSIS data sets differed from each other in the number and order of parameters recorded. Within and between the data sets there were inconsistencies in the way substances were reported, e.g. fuel-diesel, oil-diesel, fuel oil-diesel, diesel oil, and diesel fuel. In computer based sorting, different names for the same materials all appeared as different

substances, and were combined manually. Nevertheless, some potentially similar materials are listed in the inventory as separate substances, e.g. Oil with PCBs 5ppm, and Polychlorinated Biphenyls.

The presentation of quantities of materials spilled and their units of measurement was another challenge for consistency. Spills recorded in tons, pounds, barrels, gallons, liters, quarts, pints, and cups were converted to pounds and gallons.

After discarding duplicate, irrelevant, and incomplete records, 4,736 remained to be assigned to one of the nine major drainage basins in the Chesapeake Bay region. When this task was complete, the quantities of each of the resulting 154 substances were summed and divided by seven to convert to annual loads for each of the major drainage basins.

## **UNCERTAINTY**

The origination of the information accessed for this inventory and the analyses conducted to present it in its current form involved uncertainty at multiple steps. There were opportunities for both systematic and random errors to enter the process. The major attributes of concern where uncertainty in the recorded data may arise involve location of spill, identification of substance, and estimation of quantity spilled. There is also almost total uncertainty associated with sources of toxics to the Bay which are not part of the recorded information analyzed for this inventory, but which represent toxics released as a result of normal activities such as fuel combustion by-products and leached wood preservatives and antifoulant paints.

During the analyses of data for this inventory, the data were discarded if the location information associated with a spill record was insufficient to allow the assignment of a Bay region major drainage basin. It was clear from the raw data that there was a large number of compound and duplicate entries. The compound entries, which included multiple substances spilled in a single incident, were disaggregated such that each substance constituted a separate record. Duplicate entries originated from the combining of data from two sources and from multiple entries in the same data bases. Obvious duplicates were eliminated by examination after sorting the records by date, time of day, location, substance, and quantity information.

Illegal discharges are likely to be reported only if they are observed by another party. Those that are recorded in the ERNS and MSIS data bases often have only the sketchiest of information with respect to substance identification and quantity spilled. Another systematic source of uncertainty arises from the purpose for which the data bases are created and maintained, as distinguished from this inventory. Both the ERNS and MSIS exist to assist agencies to respond to environmental emergencies and account for their activities; whereas, this inventory is created to identify the most accurate information on toxics loadings to identify and reduce their impacts on the living resources in the Bay. The recorded quantities of materials spilled were likely based on estimates in most cases, especially where no source could be

identified. Some records included an estimate of the quantity of spilled material which was subsequently recovered. The records of quantity recovered refer to substance spilled, and do not include associated water which may also have been picked up in the recovery process. Where this information was given, the data were adjusted to present the net spill for this inventory. There is uncertainty with regard to this issue, because most records are based on initial notification of a spill in order to fulfill the requirements of the responding organization and are not necessarily up-dated with information concerning recovery operations conducted after spill information was first recorded.

## **DISCUSSION**

In total, many thousands of pounds of pollutants were spilled or discharged to the tidal waters of the Chesapeake Bay and its tributaries during the period 1990 through 1996. In particular, 154 substances were reported spilled in 4,736 recorded incidents.

A number of the recorded discharges contained chemicals on the Chesapeake Bay Toxics of Concern and Chemicals of Potential Concern lists. Those materials and recorded average annual amounts discharged to each major Chesapeake Bay drainage basins are presented in Table 4.2.

The analysis of all the data show that many substances were spilled in relatively small amounts. However, a significant number were spilled in relatively large amounts (see Table 4.3). Those with average annual spills in excess of 1,000 pounds or 1,000 gallons include: ammonium sulfate, asphalt, corrosive water, cyclohexanone, jet fuel, gasoline, diesel oil, other heavier fuel and lubricating oils, unknown and waste oily substances, polychlorinated biphenyls, sulfuric acid, and industrial waste water.

With regard to geographical distribution, a significant amount of spilled materials were discharged to the mainstem of the Bay. However, several of the tidal tributaries received the bulk of the spills. In particular, the tidal James River (including its tidal tributaries in the vicinity of Hampton Roads) received the largest quantities in many categories of substances. These appeared to be mainly associated with the large naval and air force installations in the region. The West Chesapeake Basin which includes the port and industrial areas in the Baltimore region also received a large number of spills of many substances. The least amounts of materials were spilled in the tidal areas of the Rappahannock River and Susquehanna River.

Although even small spills of toxic and hazardous substances are required by law to be reported to emergency management agencies, it is a fair assumption that an unknown--and potentially large--number of such spills never do get reported. Other systematic unrecorded sources of toxics loadings to the Bay involve the leaching of preservatives and antifoulants. Creosote and/or arsenic compounds are present in most wood products which are used for exposed applications in or near tidal waters. Some of these preservative materials eventually



leach into the Bay. There are also large numbers of commercial and recreational water craft on the Bay and its tidal tributaries; and it can be assumed that most of these vessels use antifoulant hull paints containing tin or copper which leach over time into the Bay. In addition, water craft fuel combustion by-products and expended lubricants are delivered directly to tidal waters through exhaust ports and propeller shaft bearings in the course of normal boating and shipping activities. And, in spite of pump-out facilities and regulations to the contrary, it must be assumed that some sewage generated on-board with associated deodorizers and treatment chemicals gets discharged to tidal waters from commercial and recreational water craft.

## **CORRELATION WITH 1994 TOXICS LOADING AND RELEASE INVENTORY**

Both the present work and the Shipping and Boating Loadings section of the 1994 TLRI estimated spill loadings to Chesapeake Bay and its tidal tributaries by accessing the US Coast Guard MSIS data base. However, there are significant differences in methodology between this analysis and those of the 1994 TLRI.

In this analysis, data from the MSIS were supplemented by data from the US EPA ERNS data base. Also in this work, where information existed with regard to recovery of spilled material, that information was used to develop net spilled quantities. Net spilled quantities were not calculated and reported in the 1994 TLRI. Where spill location information was missing, vague, or clearly indicated a spill inland or one to the Atlantic side of the Delmarva Peninsula, the records were discarded in this work. Location screening for the 1994 TLRI was on a coarser scale, resulting in some reported spills likely not entering the Bay's tidal waters.

With regard to substances spilled and their distribution among the major drainage basins of the Bay, the results of the present work show strong similarities to the 1994 TLRI.

## **RECOMMENDATIONS**

With regard to federal, state, and regional data bases, it is understandable that there is some desire for development, use, and maintenance at each level of government. However, all information should periodically be consolidated in one national data base for wider coverage on a consistent basis. For ease of future analysis, there should be an effort to harmonize reported information and its quality.

In so far as possible, spill attributes and their values or identifiers should be selected from predetermined lists in order to avoid problems of inconsistency such as multiple names for the same substance being entered in different records and the occurrence of spelling errors in the data bases.

In order to develop a more complete mass balance of toxic pollutants delivered directly to the tidal waters of the Bay and its tributaries, estimates of systematic pollution from the "normal"

### ***Shipping and Boating Loadings***

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use of products, as distinct from spills, should be conducted. Such products and usages include wood preservatives, antifoulant coatings, marine fuel combustion by-products, etc.

Toxic materials are incorporated in compounds and products with uncertain and unreported concentrations; therefore, it is hard to combine information on spills with the results of monitoring programs which identify specific elements and compounds in measured concentrations. Some work to establish concentrations of toxic elements and compounds of concern in commonly spilled substances would assist in the combining of spill data with monitoring results.

A specific universal system (e.g., latitude/longitude) of spill location should be incorporated into recorder information for ease of analysis and graphical representation.

Table 4.1. Chemicals Selected for the 1996 Chesapeake Bay Toxics of Concern List, the Chemicals of Potential Concern List, and Delisted Chemicals.

Toxics of Concern List		Chemicals of Potential Concern		Chemicals Removed	
Current List (1990)	Proposed Revised List	Current List (1990)	Proposed Revised List	From Toxics of Concern List	From Chemicals of Potential Concern List
		Alachlor			Alachlor
		Aldrin			Aldrin
		Arsenic	Arsenic		
Atrazine				Atrazine	
Benz[a]anthracene			Other PAHs <sup>1</sup>		
Benzo[a]pyrene			1		
Cadmium			Cadmium		
Chlordane	Chlordane				
Chromium			Chromium		
Chrysene			Chrysene		
Copper	Copper				
		Dieldrin	Dieldrin		
					Diflubenzuron <sup>3</sup>
		Fenvalerate			Fenvalerate
Fluoranthene	Fluoranthene				
Lead	Lead				
Mercury			Mercury		
		Metolachlor			Metolachlor
Naphthalene	Naphthalene				
			Nickel		
		Permethrin			Permethrin
	Phenanthrene				
PCBs	Arochlor 1260		Other PCBs <sup>2</sup>		
			Pyrene		
Tributyltin (TBT)	Tributyltin (TBT)				
		Toxaphene			Toxaphene
		Zinc	Zinc		

Bold indicates new additions to the Toxics of Concern and Chemicals of Potential Concern Lists.

<sup>1</sup> Other PAHs include: benzo[b]fluoranthene, benz[a]anthracene, benzo[a]pyrene, benzo[e]pyrene, acenaphthene, dibenzo[a,h]anthracene, fluorene, 2-methyl naphthalene, pyrene, benzo[g,h,i]perylene, ideno[1,2,3,cd]pyrene. Note that benzo[a]pyrene and benz[a]anthracene were previously listed as Toxics of Concern.

<sup>2</sup> Other PCBs include: PCB congeners 126 and 169, PCB Arochlors 1016, 1232, 1242, 1248, pentachlorobiphenyls, tetrachlorobiphenyls, and polychlorinated biphenyl.

<sup>3</sup> Diflubenzuron was removed from the Chemicals of Potential Concern List in 1992 with the approval of the Toxics Subcommittee.

Table 4.2a. Spills of Toxic Materials Containing Chemicals on the Chesapeake Bay Toxics of Concern and Chemicals of Potential Concern Lists.

From Ships and Land Facilities to the Chesapeake Bay and Its Tidal Tributaries

(Average annual spill loadings: 1990-1996) Ranked alphabetically by substance

	ToC/CoPC*	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
ARSENIC TRIOXIDE	2	GAL	10.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CADMIUM SULFATE	2	LBS	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHROMIC ANHYDRIDE	2	GAL	185.7	0.0	185.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHROMIC ANHYDRIDE	2	LBS	1.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COPPER, SOFT	1	GAL	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
LEAD NITRATE	1	LBS	5.6	0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0
LEAD SULFATE	1	LBS	8.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	2.1
NAPHTHALENE (MOLTEN)	1	GAL	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
OIL WITH PCB'S 5PPM	2	GAL	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
POLYCHLORINATED BIPHENYLS	2	GAL	1245.9	0.0	4.3	0.0	1235.9	0.0	0.0	5.7	0.0	0.0
ZINC ORTHOPHOSPHATE	2	GAL	114.3	0.0	0.0	0.0	0.0	0.0	0.0	114.3	0.0	0.0

\*1 Material Containing Chemical on the Chesapeake Bay Toxics of Concern List (Rev. March 6, 1997)

2 Material Containing Chemical on the Chesapeake Bay Chemicals of Potential Concern List (Rev. March 6, 1997)

Table 4.2b. Spills of Toxic Materials Containing Chemicals on the Chesapeake Bay Toxics of Concern and Chemicals of Potential Concern Lists.

From Ships and Land Facilities to the Chesapeake Bay and Its Tidal Tributaries

(Average annual spill loadings: 1990-1996) Ranked by Annual Total Loading

	ToC/CoPC*	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
POLYCHLORINATED BIPHENYLS	2	GAL	1245.9	0.0	4.3	0.0	1235.9	0.0	0.0	5.7	0.0	0.0
CHROMIC ANHYDRIDE	2	GAL	185.7	0.0	185.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZINC ORTHOPHOSPHATE	2	GAL	114.3	0.0	0.0	0.0	0.0	0.0	0.0	114.3	0.0	0.0
ARSENIC TRIOXIDE	2	GAL	10.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LEAD SULFATE	1	LBS	8.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	2.1
LEAD NITRATE	1	LBS	5.6	0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0
CHROMIC ANHYDRIDE	2	LBS	1.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COPPER, SOFT	1	GAL	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
OIL WITH PCB'S 5PPM	2	GAL	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
CADMIUM SULFATE	2	LBS	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NAPHTHALENE (MOLTEN)	1	GAL	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

\*1 Material Containing Chemical on the Chesapeake Bay Toxics of Concern List (Rev. March 6, 1997)

2 Material Containing Chemical on the Chesapeake Bay Chemicals of Potential Concern List (Rev. March 6, 1997)

Table 4.2c. Spills of Toxic Materials Containing Chemicals on the Chesapeake Bay Toxics of Concern and Chemicals of Potential Concern Lists.

From Ships and Land Facilities to the Chesapeake Bay and Its Tidal Tributaries

(Average annual spill loadings: 1990-1996) Ranked alphabetically by substance

	ToC/CoPC*	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
ARSENIC TRIOXIDE	2	GAL	10.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CADMIUM SULFATE	1	LBS	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHROMIC ANHYDRIDE	1	GAL	185.7	0.0	185.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHROMIC ANHYDRIDE	1	LBS	1.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COPPER, SOFT	1	GAL	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
LEAD NITRATE	1	LBS	5.6	0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0
LEAD SULFATE	1	LBS	8.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	2.1
NAPHTHALENE (MOLTEN)	1	GAL	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
OIL WITH PCB'S 5PPM	1	GAL	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
POLYCHLORINATED BIPHENYLS	1	GAL	1245.9	0.0	4.3	0.0	1235.9	0.0	0.0	5.7	0.0	0.0
ZINC ORTHOPHOSPHATE	2	GAL	114.3	0.0	0.0	0.0	0.0	0.0	0.0	114.3	0.0	0.0

\*1 Material Containing Chemical on the Chesapeake Bay Toxics of Concern List (1990)

2 Material Containing Chemical on the Chesapeake Bay Chemicals of Potential Concern List (1990)

Table 4.2d. Spills of Toxic Materials Containing Chemicals on the Chesapeake Bay Toxics of Concern and Chemicals of Potential Concern Lists.

From Ships and Land Facilities to the Chesapeake Bay and Its Tidal Tributaries

(Average annual spill loadings: 1990-1996) Ranked by Annual Total Loading

	ToC/CoPC*	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
POLYCHLORINATED BIPHENYLS	1	GAL	1245.9	0.0	4.3	0.0	1235.9	0.0	0.0	5.7	0.0	0.0
CHROMIC ANHYDRIDE	1	GAL	185.7	0.0	185.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZINC ORTHOPHOSPHATE	2	GAL	114.3	0.0	0.0	0.0	0.0	0.0	0.0	114.3	0.0	0.0
ARSENIC TRIOXIDE	2	GAL	10.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LEAD SULFATE	1	LBS	8.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	2.1
LEAD NITRATE	1	LBS	5.6	0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0
CHROMIC ANHYDRIDE	1	LBS	1.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COPPER, SOFT	1	GAL	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
CADMIUM SULFATE	1	LBS	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OIL WITH PCB'S 5PPM	1	GAL	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
NAPHTHALENE (MOLTEN)	1	GAL	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

\*1 Material Containing Chemical on the Chesapeake Bay Toxics of Concern List (1990)

2 Material Containing Chemical on the Chesapeake Bay Chemicals of Potential Concern List (1990)

Table 4.3a. Spills of Toxic Materials from Ships and Land Facilities to the Chesapeake Bay and Its Tidal Tributaries.

(Average annual spill loadings: 1990-1996)

Ranked by Annual Total Loading

Ranked by Annual Total Loading	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
AMMONIUM SULFATE	LBS	467714.3									467714.3
OIL, MISC: LUBRICATING	GAL	23362.6	2.9	256.1	0.4	4.6		19.4	23063.1	4.7	11.3
OIL, DIESEL	GAL	10792.4	8.9	924.0	25.1	142.1	107.1	90.4	7778.7	156.0	1560.0
CORROSIVE WATER PH LEVEL 11.5	GAL	10000.0							10000.0		
FUEL, JET: JP-5	GAL	7030.1			69.0	94.3		4.1	6559.3		303.4
OIL, FUEL: NO. 2-D	GAL	6642.7		489.9	2.6	183.4	4.3	1860.1	4038.6	45.9	18.0
ASPHALT	GAL	4705.7		4705.7							
OIL, FUEL: NO. 4	GAL	4593.7		496.3		58.9			4038.6		
WASTE WATER, INDUSTRIAL	GAL	4591.0		176.0					4415.0		
OIL, UNKNOWN	GAL	3374.4		697.9	0.3	113.6	4.7	22.9	2452.0	35.7	47.4
OIL, WASTE	GAL	3339.0		1557.0		0.6	3.0	12.4	1610.3	82.3	73.4
CYCLOHEXANONE	LBS	3244.3							3244.3		
OIL, FUEL: NO. 2	GAL	3003.0	41.4	623.3	15.4	679.7	0.7	108.1	1310.1	68.0	156.1
SULFURIC ACID	GAL	2525.1		71.4	10.7	28.6			1271.4		1143.0
OIL, FUEL: NO. 6	GAL	1673.7		426.3		39.4	7.1	0.1	440.4	702.4	57.9
POLYCHLORINATED BIPHENYLS	GAL	1245.9		4.3		1235.9			5.7		
UNKNOWN	GAL	1037.1		48.4		1.1		3.3	975.6	6.6	2.1
CORROSION INHIBITOR/MICR IN WATER	GAL	900.0							900.0		
GASOLINE, AUTOMOTIVE (UNLEADED)	GAL	744.6	21.4	40.3	0.1	32.4		0.9	49.3	15.0	585.1
GASOLINE, AUTOMOTIVE (4.23G PB/G)	GAL	627.6	3.3	186.3	1.1	60.6	2.9	31.3	202.7	26.4	113.0
FERRIC ACID	GAL	571.4				571.4					
CAPROLACTAM SOLUTION	LBS	479.0							479.0		
AMMONIA, ANHYDROUS	LBS	478.6		428.6							50.0
OIL, FUEL	GAL	467.6		2.1		28.6			436.9		
SEWAGE	GAL	461.7		172.9				271.3	10.4		7.1
CHLORINE SOLUTION	GAL	457.1							457.1		



	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
OIL, CRUDE	GAL	436.4		130.1				0.3	300.3		5.7
SULFURIC ACID	LBS	389.3							389.3		
OIL, WASH	GAL	378.9		350.3						28.6	
CORROSION INHIBITOR	LBS	358.4							358.4		
CAPROLACTAM SOLUTION	GAL	357.1							357.1		
CYCLOHEXANONE	GAL	357.1							357.1		
OIL, FUEL: NO. 5	GAL	353.1		353.1							
COAL DUST	LBS	318.6		12.3					304.9		1.4
PHOSPHATE, ORGANIC	GAL	271.4							271.4		
AQUEOUS FIRE FIGHTING FOAM	GAL	262.1							247.9		14.3
OIL, HYDRAULIC	GAL	257.7	0.7	2.7		8.7		2.7	216.6	16.7	9.6
SODIUM HYDROXIDE	LBS	242.9				242.9					
CHROMIC ANHYDRIDE	GAL	185.7		185.7							
SODIUM HYDROXIDE	GAL	179.3	12.9			166.4					
FERRIC CHLORIDE	GAL	151.4		7.9		143.6					
ETHYLENE GLYCOL	GAL	132.9		45.0		57.1		0.1	8.1		22.4
FUEL, JET: JP-4	GAL	128.7						107.9	20.9		
RESIN, AMBERLITE IR-122	GAL	128.6									128.6
TCLP ASH OR KO44 WASTE	LBS	120.0				120.0					
ZINC ORTHOPHOSPHATE	GAL	114.3							114.3		
KEROSENE	GAL	109.7		43.4				2.3	9.7		54.3
OIL, MISC: MOTOR	GAL	101.7		24.9	0.4	2.9		0.3	70.0	1.9	1.4
PESTICIDE	GAL	71.4		71.4							
DISTILLATES: FLASHED FEED STOCKS	GAL	71.4							71.4		
ALKYLATE	GAL	71.4		71.4							
FLY ASH	LBS	71.4							71.4		
DYE	GAL	64.3		0.7					60.0		3.6
OIL, MISC: TRANSFORMER	GAL	57.9	2.1	15.1		32.9		2.9	3.1		1.7
OIL, MISC: BUNKER C	GAL	51.0							51.0		
ETHYLENE GLYCOL	LBS	50.4							50.4		



	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
COSMOLINE	GAL	7.9						0.1	7.7		
ALUMINUM CHLORIDE LIQUOR	LBS	7.4		7.4							
GASOLINE, AVIATION (4.86 G PB/GAL)	GAL	7.3		7.1					0.1		
OIL, DECANTED	GAL	7.3						0.1	7.1		
OIL, COAL TAR	GAL	7.1									7.1
OIL, MISC: TURBINE	GAL	6.0	0.3	5.7							
PAINT, MISC.	GAL	5.9		2.9				1.4	1.6		
LEAD NITRATE	LBS	5.6				5.6					
OIL, LIGHT	GAL	5.4		0.1				0.3	5.0		
DICHLOROMONOFUOROMETHANE	GAL	5.3						4.6	0.7		
PAINT THINNER	GAL	5.1							5.1		
OIL, TRANSMISSION	GAL	5.1		0.6					4.6		
OIL, COOKING	GAL	5.0		0.7					4.3		
ETHO CHLORO HYDRINE	GAL	4.6							4.6		
OIL, HEAT TRANSFER -MOBIL THERM 60	GAL	4.3		4.3							
OIL, FUEL: IF 30 GRADE SHIP	GAL	4.3							4.3		
ASPHALT BLENDING STOCKS: STRAIGHT RUN RESIDUE	GAL	4.1		3.6							0.6
OIL, MISC: ROAD	GAL	3.7		3.7							
PAINT CHIPS	GAL	3.6							3.6		
POLYVINYL ACETATE EMULSION	GAL	3.6							3.6		
OIL, FUEL: NAVY STANDARD	GAL	3.6							3.6		
GASOLINE, AROMATIC	GAL	3.6							3.6		
PAINT, EPOXY	GAL	3.1							2.7		0.4
OIL, THERMAL	GAL	2.9							2.9		
PETROLATUM	GAL	2.3				0.1			2.1		
CARBARYL SOLUTION (INSECTICIDE)	GAL	2.1							2.1		
FERTILIZER	GAL	2.1							2.1		



	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
CADMIUM SULFATE	LBS	0.3		0.3							
OIL WITH PCB'S 5PPM	GAL	0.3				0.3					
OIL, GAS: CRACKED	GAL	0.3						0.3			
PETROLEUM PRODUCT	GAL	0.3							0.3		
METRO SPERSE #269	GAL	0.1	0.1								
MTBE, GAS ADDITIVE	GAL	0.1						0.1			
NAPHTHALENE (MOLTEN)	GAL	0.1									0.1
LATEX, SYNTHETIC	LBS	0.1		0.1							
OIL, EDIBLE: WALNUT	GAL	0.1							0.1		
CARBON	LBS	0.1							0.1		
HYDROFLUORIC ACID	GAL	0.1							0.1		
OIL, GAS	GAL	0.1						0.1			
OIL, MISC: SPINDLE	GAL	0.1									0.1
SOOT	GAL	0.1		0.1							
ALUMINUM SULFATE	GAL	0.1				0.1					
METHYL CHLORIDE	GAL	0.1							0.1		
PHOSPHORIC SOLUTION < RQ	GAL	0.1		0.1							
OIL, MISC: RANGE	GAL	0.1				0.1					

Table 4.3b. Spills of Toxic Materials from Ships and Land Facilities to the Chesapeake Bay and Its Tidal Tributaries.

(Average annual spill loadings: 1990-1996)

Ranked alphabetically by substance

	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
2-2 BUTOXY ETHOXI	LBS	15.0									15.0
ALKYLATE	GAL	71.4		71.4							
ALUMINUM CHLORIDE LIQUOR	LBS	7.4		7.4							
ALUMINUM SULFATE	GAL	0.1				0.1					
AMMONIA, ANHYDROUS	LBS	478.6		428.6							50.0
AMMONIUM SULFATE	LBS	467714.3									467714.3
ANTI-FREEZE	GAL	0.3							0.3		
AQUEOUS FIRE FIGHTING FOAM	GAL	262.1							247.9		14.3
ARSENIC TRIOXIDE	GAL	10.0		10.0							
ASPHALT	GAL	4705.7		4705.7							
ASPHALT BLENDING STOCKS: ROOFERS FLUX	GAL	21.4		21.4							
ASPHALT BLENDING STOCKS: STRAIGHT RUN RESIDUE	GAL	4.1		3.6							0.6
BATTERY, ATON	LBS	32.1							2.1		30.0
BILGE WATER WITH RESIDUAL OIL	GAL	38.6		7.7	0.4				30.4		
BUTYL CARBITOL	LBS	0.6							0.6		
CADMIUM SULFATE	LBS	0.3		0.3							
CAPROLACTAM SOLUTION	GAL	357.1							357.1		
CAPROLACTAM SOLUTION	LBS	479.0							479.0		
CARBARYL SOLUTION (INSECTICIDE)	GAL	2.1							2.1		
CARBON	LBS	0.1							0.1		
CHLORINE SOLUTION	GAL	457.1							457.1		
CHLORINE SOLUTION	LBS	1.7							1.7		
CHROMIC ANHYDRIDE	GAL	185.7		185.7							
CHROMIC ANHYDRIDE	LBS	1.1		1.1							
COAL DUST	LBS	318.6		12.3					304.9		1.4

	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
COPPER, SOFT	GAL	0.7						0.7			
CORROSION INHIBITOR	LBS	358.4							358.4		
CORROSION INHIBITOR/MICR IN WATER	GAL	900.0							900.0		
CORROSIVE WATER PH LEVEL 11.5	GAL	10000.0							10000.0		
COSMOLINE	GAL	7.9						0.1	7.7		
COSTIC SODA SOLUTION	GAL	43.0							42.9		0.1
CREOSOTE (COAL TAR)	GAL	0.7							0.7		
CYCLOHEXANONE	GAL	357.1							357.1		
CYCLOHEXANONE	LBS	3244.3							3244.3		
DETERGENT/DEGREASER	GAL	12.1	0.3	6.7				2.9	2.3		
DFM	GAL	1.4							1.4		
DICHLOROMONOFUOROMETHANE	GAL	5.3						4.6	0.7		
DISTILLATES: FLASHED FEED STOCKS	GAL	71.4							71.4		
DREDGE SPOILS	GAL	0.3							0.3		
DYE	GAL	64.3		0.7					60.0		3.6
ETHO CHLORO HYDRINE	GAL	4.6							4.6		
ETHYLENE GLYCOL	GAL	132.9		45.0		57.1		0.1	8.1		22.4
ETHYLENE GLYCOL	LBS	50.4							50.4		
FERRIC ACID	GAL	571.4				571.4					
FERRIC CHLORIDE	GAL	151.4		7.9		143.6					
FERTILIZER	GAL	2.1							2.1		
FLOCOAT	GAL	0.9							0.9		
FLY ASH	LBS	71.4							71.4		
FUEL, JET: JP-4	GAL	128.7						107.9	20.9		
FUEL, JET: JP-5	GAL	7030.1			69.0	94.3		4.1	6559.3		303.4
FUEL, JET: JP-8	GAL	20.1		0.1				15.0	5.0		
FUEL, MARINE DIESEL	GAL	16.0		1.4					14.6		
FUEL, ROCKET	LBS	49.7				49.7					
G BASE	GAL	1.4		1.4							

	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
GASOLINE	GAL	24.6		20.0		3.6			0.7	0.3	
GASOLINE BLENDING STOCKS: ALKYLATES	GAL	0.7		0.7							
GASOLINE, AROMATIC	GAL	3.6							3.6		
GASOLINE, AVIATION (4.86 G PB/GAL)	GAL	7.3		7.1					0.1		
GASOLINE, AUTOMOTIVE (4.23G PB/G)	GAL	627.6	3.3	186.3	1.1	60.6	2.9	31.3	202.7	26.4	113.0
GASOLINE, AUTOMOTIVE (UNLEADED)	GAL	744.6	21.4	40.3	0.1	32.4		0.9	49.3	15.0	585.1
GREASE, MISC.	GAL	0.3		0.3							
HYDRAZINE	GAL	0.4			0.4						
HYDROCHLORIC ACID	GAL	16.1				14.3			1.9		
HYDROFLUORIC ACID	GAL	0.1							0.1		
HYDROGEN PEROXIDE	GAL	10.0								10.0	
KEROSENE	GAL	109.7		43.4				2.3	9.7		54.3
LATEX, LIQUID NATURAL	GAL	12.9		11.4					1.4		
LATEX, SYNTHETIC	LBS	0.1		0.1							
LEAD NITRATE	LBS	5.6				5.6					
LEAD SULFATE	LBS	8.0							5.9		2.1
METHYL CHLORIDE	GAL	0.1							0.1		
METRO SPERSE #269	GAL	0.1	0.1								
MTBE, GAS ADDITIVE	GAL	0.1						0.1			
NAPHTHALENE (MOLTEN)	GAL	0.1									0.1
NITROGEN, LIQUEFIED	GAL	42.9							42.9		
OIL WITH PCB'S 5PPM	GAL	0.3				0.3					
OIL, BLACK	GAL	1.4							1.4		
OIL, COAL TAR	GAL	7.1									7.1
OIL, COOKING	GAL	5.0		0.7					4.3		
OIL, CRUDE	GAL	436.4		130.1				0.3	300.3		5.7
OIL, DECANTED	GAL	7.3						0.1	7.1		
OIL, DIESEL	GAL	10792.4	8.9	924.0	25.1	142.1	107.1	90.4	7778.7	156.0	1560.0



	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
OIL, EDIBLE: FISH	GAL	1.0		1.0							
OIL, EDIBLE: SOYA BEAN	GAL	0.9							0.9		
OIL, EDIBLE: VEGETABLE	GAL	0.9		0.3					0.6		
OIL, EDIBLE: WALNUT	GAL	0.1							0.1		
OIL, EMULSIFIED	GAL	1.4							1.4		
OIL, FUEL	GAL	467.6		2.1		28.6			436.9		
OIL, FUEL: F-76	GAL	35.9							35.9		
OIL, FUEL: IF 30 GRADE SHIP	GAL	4.3							4.3		
OIL, FUEL: INTERMEDIATE (IFO 180)	GAL	22.6		9.7					12.9		
OIL, FUEL: INTERMEDIATE 380 INNERMIX	GAL	0.7		0.7							
OIL, FUEL: NAVY SPECIAL	GAL	0.7						0.7			
OIL, FUEL: NAVY STANDARD	GAL	3.6							3.6		
OIL, FUEL: NO. 1	GAL	15.9		12.9	0.1				2.9		
OIL, FUEL: NO. 1-D	GAL	19.1	0.4	6.1	1.4						11.1
OIL, FUEL: NO. 2	GAL	3003.0	41.4	623.3	15.4	679.7	0.7	108.1	1310.1	68.0	156.1
OIL, FUEL: NO. 2-D	GAL	6642.7		489.9	2.6	183.4	4.3	1860.1	4038.6	45.9	18.0
OIL, FUEL: NO. 4	GAL	4593.7		496.3		58.9			4038.6		
OIL, FUEL: NO. 5	GAL	353.1		353.1							
OIL, FUEL: NO. 6	GAL	1673.7		426.3		39.4	7.1	0.1	440.4	702.4	57.9
OIL, GAS	GAL	0.1						0.1			
OIL, GAS: CRACKED	GAL	0.3						0.3			
OIL, GAS: DESULFURIZED	GAL	1.4						1.4			
OIL, HEAT TRANSFER -MOBIL THERM 60	GAL	4.3		4.3							
OIL, HOME HEATING	GAL	10.0		5.7							4.3
OIL, HYDRAULIC	GAL	257.7	0.7	2.7		8.7		2.7	216.6	16.7	9.6
OIL, LIGHT	GAL	5.4		0.1				0.3	5.0		
OIL, MISC: BUNKER C	GAL	51.0							51.0		
OIL, MISC: LUBRICATING	GAL	23362.6	2.9	256.1	0.4	4.6		19.4	23063.1	4.7	11.3
OIL, MISC: MINERAL	GAL	8.6		5.0					3.6		

	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
OIL, MISC: MOTOR	GAL	101.7		24.9	0.4	2.9		0.3	70.0	1.9	1.4
OIL, MISC: PETROLEUM DISTILLATE	GAL	28.6							28.6		
OIL, MISC: RANGE	GAL	0.1				0.1					
OIL, MISC: RESIN	GAL	0.3							0.1		0.1
OIL, MISC: ROAD	GAL	3.7		3.7							
OIL, MISC: SPINDLE	GAL	0.1									0.1
OIL, MISC: SPRAY	GAL	0.3		0.1		0.1					
OIL, MISC: TRANSFORMER	GAL	57.9	2.1	15.1		32.9		2.9	3.1		1.7
OIL, MISC: TURBINE	GAL	6.0	0.3	5.7							
OIL, TERRESTIC	GAL	0.6		0.6							
OIL, THERMAL	GAL	2.9							2.9		
OIL, TRANSMISSION	GAL	5.1		0.6					4.6		
OIL, UNKNOWN	GAL	3374.4		697.9	0.3	113.6	4.7	22.9	2452.0	35.7	47.4
OIL, WASH	GAL	378.9		350.3						28.6	
OIL, WASTE	GAL	3339.0		1557.0		0.6	3.0	12.4	1610.3	82.3	73.4
PAINT CHIPS	GAL	3.6							3.6		
PAINT THINNER	GAL	5.1							5.1		
PAINT, EPOXY	GAL	3.1							2.7		0.4
PAINT, LATEX	GAL	1.6							1.6		
PAINT, MISC.	GAL	5.9		2.9				1.4	1.6		
PAINT, OIL BASED	GAL	28.9	2.1	2.4		7.1			16.6		0.6
PARRAFIN/OLEFIN WAX/ NON-REGULATED/NON-HAZARD	GAL	19.0		4.3				0.3	13.4		1.0
PESTICIDE	GAL	71.4		71.4							
PETROLATUM	GAL	2.3				0.1			2.1		
PETROLEUM PRODUCT	GAL	0.3							0.3		
PHENOL	LBS	0.6							0.6		
PHOSPHATE, ORGANIC	GAL	271.4							271.4		
PHOSPHORIC SOLUTION < RQ	GAL	0.1		0.1							
POLLEN	LBS	15.7							15.7		
POLYCHLORINATED BIPHENYLS	GAL	1245.9		4.3		1235.9			5.7		

	Units	An. Total	Susqueh.	W. Ches.	Patuxent	Potomac	Rappah.	York	James	E. Shore	Mainstem
POLYVINYL ACETATE EMULSION	GAL	3.6							3.6		
POTASSIUM HYDROXIDE	GAL	14.3		14.3							
PRESERVATIVE	GAL	8.1							8.1		
RC250	GAL	0.7						0.7			
RESIN, AMBERLITE IR-122	GAL	128.6									128.6
SEWAGE	GAL	461.7		172.9				271.3	10.4		7.1
SOAP	GAL	1.4									1.4
SODIUM HYDROXIDE	GAL	179.3	12.9			166.4					
SODIUM HYDROXIDE	LBS	242.9				242.9					
SOOT	GAL	0.1		0.1							
SULFURIC ACID	GAL	2525.1		71.4	10.7	28.6			1271.4		1143.0
SULFURIC ACID	LBS	389.3							389.3		
TAR BALLS	GAL	10.6						0.1	5.1		5.3
TCLP ASH OR KO44 WASTE	LBS	120.0				120.0					
TURPENTINE	GAL	0.7							0.7		
UNKNOWN	GAL	1037.1		48.4		1.1		3.3	975.6	6.6	2.1
WASTE WATER, INDUSTRIAL	GAL	4591.0		176.0					4415.0		
ZINC ORTHOPHOSPHATE	GAL	114.3							114.3		

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## CHAPTER 5 - Acid Mine Drainage Loadings

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### INTRODUCTION

Land use activities in the Chesapeake Bay watershed are diverse and contribute significantly to water quality. Because of the long history of coal mining in the upper reaches of the Chesapeake Bay watershed, much concern has been generated regarding the impact of acid drainage from abandoned coal mines. It is believed that active mines are not a significant source of contaminants to the Bay since they are permitted, controlled, and treatment programs are in place. The U.S. Environmental Protection Agency has singled out acid drainage from abandoned coal mines as the number one water quality problem in Appalachia. The *1994 Chesapeake Bay Basinwide Toxics Reduction and Prevention Strategy* calls for establishing more complete baseline loadings and source identification for acid mine drainage and setting reduction targets to be achieved over the next decade. The Toxics Subcommittee funded a literature synthesis to provide initial loadings estimate for acid mine drainage and methodologies for remediation. The key loadings information from this literature synthesis is summarized in this chapter. This is the first time that acid mine drainage loadings have been reported in the Toxics Loadings and Release Inventory.

Acid mine drainage from abandoned coal mines has been considered the most severe and extensive water pollution problem in western Maryland, West Virginia, and northeast, north central and western Pennsylvania. Within the Chesapeake Bay Basin, drainage from abandoned coal mines poses a significant threat to water quality in the Susquehanna, West Branch Susquehanna, and Juniata River basins in Pennsylvania, as well as the North Branch Potomac River and its tributaries in West Virginia and Maryland.

Acid mine drainage (AMD) is formed when mining operations expose coal and bedrock high in pyrite (iron-disulfide) to oxygen and moisture. The drainage is characterized by low pH (less than 6.0) and high concentrations of sulfates, acidity, and metals (dissolved/particulate) such as iron, manganese and aluminum. Other principal elements of coal mine drainage include calcium, magnesium, sodium and potassium (Clark, 1969). Additional trace metals that have been detected in AMD in decreasing order of abundance are strontium, zinc, nickel, cobalt, lithium, barium, boron, copper, lead and cadmium (Wood, 1996).

Factors that affect the concentrations of AMD chemical constituents in coal mine drainage are mineral content of the coal, overburden (material above the coal deposits), and associated host rock; quantity of water flowing through the mine workings; residence time of water circulation in

### ***Acid Mine Drainage Loadings***

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mine workings; the availability of oxygen and dissolved oxygen in the mine water; method of mining (e.g., deep underground or surface mining); water removal from mines through pumping; and the exposed surface area of pyritic minerals.

Efforts to characterize AMD discharges must consider the common variability in flow and quality. Drainage occurs through various entryways to the mine (e.g., tunnels, shafts, slopes and drifts). Deep mine discharges in the Anthracite Region are less numerous than in the Bituminous Field, but contribute a much higher acid loading per discharge. Surface or strip mines in both Anthracite and Bituminous regions also contribute to AMD. Improperly graded strip pits can trap surface runoff and form pools containing high concentrations of dissolved salts. During periods of heavy rainfall, the strip mine pools may overflow and discharge acidic water into nearby streams. Water trapped in the mine pits frequently emerges as seeps downslope from the mine site causing pollution of receiving streams. Leachate from coal refuse piles associated with abandoned mine sites are common sources of AMD. Refuse piles usually cover large areas and provide a source of minerals for the formation of acid drainage.

### **TEMPORAL AND SPATIAL COVERAGE**

Chemical contaminant loadings from acid mine drainage are summarized from the following sources: the Susquehanna River Basin (Anthracite Coal Region), West Branch Susquehanna and Juniata River basins (Bituminous Coal Region) in Pennsylvania, and the North Branch Potomac River and its tributaries (Bituminous Coal Region) in West Virginia and Maryland. Much of the available data related to mine drainage was generated during early comprehensive investigations to identify impacted watersheds and sources of mine acid for the purpose of determining appropriate AMD abatement measures. These investigations, for the most part, are limited to acid, iron and sulfate loading estimates and do not contain information on additional pollutants. Consequently, there are insufficient data on other metals directly associated with mine drainage discharges to estimate loads from data in these reports.

### **METHODOLOGY**

For the most part, models used to evaluate AMD loads in surface waters have been designed to evaluate acid loading within a watershed for purposes of designing appropriate abatement measures to mitigate the adverse impact of acidic conditions. The extensive evaluations of AMD impacted watersheds conducted by engineering firms in the 1970's monitored all detectable sources of mine drainage in a watershed for chemical constituents and discharge flow data. In order to define the extent of AMD loads, it was necessary to determine the volume and chemical quality (concentrations) of mine drainage at discharge points within the watershed. In-stream water samples and flow measurements were obtained in addition to mine drainage discharge data to establish stream quality. Data used for calculating loads were generally collected at regular intervals, usually monthly, over the course of one year to evaluate loads during low, average, and high flow conditions.

## **UNCERTAINTY**

Much of the available data related to mine drainage was generated during comprehensive investigations conducted in the early 1970's and 1980's to identify impacted watersheds and sources of mine acid for the purpose of determining appropriate AMD abatement measures. Although these previous investigations thoroughly identified sources of AMD and associated loads 25-30 years ago, there is some uncertainty as to whether the historical data are currently applicable.

Estimating AMD loads from in-stream measurements downstream from all sources leads to uncertainties as to what is attributable to mine discharges versus other point and non-point sources of the chemical constituents. On the other hand, estimating loads by addition of individual discharges also has uncertainties as to what proportion of the load is ultimately delivered downstream. Biological and chemical processes in receiving streams alter chemical concentrations in mine drainage subsequent to discharge from the AMD source. Iron and aluminum, as well as other trace metals in mine drainage, commonly precipitate and coat stream beds and, through oxidative-reductive reactions, sorb and desorb from particles in the receiving stream. These processes alter the delivery of mine drainage constituents downstream. Data correlating AMD loads in upper reaches of the Chesapeake Bay watershed with loadings of contaminants entering the Bay are lacking.

## **DISCUSSION**

Acid mine drainage from abandoned coal mines is thought to be the single greatest source of pollution in the Susquehanna River Basin, West Branch Susquehanna River Subbasin and North Branch Potomac River Subbasin. Acid mine drainage has impacted 1100 mi in 158 streams in the Chesapeake Bay drainage area, as indicated in the 1996 Pennsylvania, Maryland and West Virginia 303(d) reports (Table 5.1). The causes cited for water quality degradation from AMD are, for the most part, related to pH and/or metals. Most of the mines that once produced coal are now abandoned, but continue to produce and discharge acid drainage. Acid mine drainage is characterized by low pH and elevated levels of sulfates, acidity and metals such as iron, manganese and aluminum. Although severe stream degradation from acid occurs within subwatersheds and segments of the Susquehanna River, West Branch Susquehanna River and North Branch Potomac River, natural alkaline reserves are capable of neutralizing all acid downstream from the coal regions.

***Acid Mine Drainage Loadings***

Table 5.1. Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

<b>Stream Name</b>	<b>Miles Degraded</b>
<b>Upper Susquehanna River Subbasin</b>	
Tioga River	3
Morris Run	1
Fall Brook	2
Long Valley Run	1.6
<b>Upper Central Susquehanna River Subbasin</b>	
Lackawanna River	2.6
Roaring Brook	4
Aylesworth Creek	0.5
Powderly Creek	1.9
Coal Brook	1.9
Wilson Creek	0.6
Susquehanna River	20
Newport Creek	4.8
Solomon Creek	2.4
Black Creek	4.3
Little Nescopeck Creek	9.1
Catawissa Creek	27.5
Tomhickon Creek	10.6
Sugarloaf Creek	5.5
<b>Lower Susquehanna River Subbasin</b>	
Mahanoy Creek	52.2
Zerbe Run	5.8
Crab Run	1.3
Shenandoah Creek	5
Shamokin Creek	34.7
Carbon Run	3.7
Coal Run	3
Quaker Run	1.3
Locust Creek	1.6
North Branch Shamokin Cr.	4.6
Wiconisco Creek	16.2
Rattling Creek	2.2

***Acid Mine Drainage Loadings***

Table 5.1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

<b>Stream Name</b>	<b>Miles Degraded (based on length of study segment)</b>
<b>Lower Susquehanna River Subbasin</b>	
West Branch Rattling Cr.	5.2
Doc Smith Run	1.5
Shale Run	0.8
East Branch Rattling Cr.	3.8
Stone Cabin Run	1.8
Nine O'Clock Run	0.6
Bear Creek	4.4
Pine Creek	6
Deep Creek	4.5
Hans Yost Creek	1
Rausch Creek	1.7
West Br. Rausch Cr.	3.5
East Br. Rausch Cr.	1.9
Swatara Creek	21.3
Baird Creek	1.4
West Branch Fishing Creek	3.6
Lower Rausch Creek	6.8
Lorberry Creek	1
Stumps Run	0.4
Middle Creek	17.5
Good Spring Creek	5.8
Poplar Creek	0.9
Coal Run	1.6
Gebhard Run	1.9
Panther Creek	1.7
<b>Upper West Branch Susquehanna River Subbasin</b>	
Sinnemahoning Creek	15.8
Bennett Branch Sinnemahoning Cr.	66.6
Dents Run	6.5
Trout Run	1
Spring Run	1.7
West Creek	12



***Acid Mine Drainage Loadings***

Table 5.1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

<b>Stream Name</b>	<b>Miles Degraded (based on length of study segment)</b>
<b>Upper West Branch Susquehanna River Subbasin (cont'd)</b>	
Montgomery Creek	2.6
West Branch Susquehanna River	79.7
Laurel Run	1
Woods Run	3
North Branch Montgomery Cr.	0.9
Tinker Run	0.7
Hartshorn Run	1
Anderson Creek	10.3
Kratzer Run	5.1
Irvin Branch	1.5
Little Anderson Cr.	5.7
Wilson Run	1
North Camp Run	1.4
Rock Run	3
Bear Run	2.9
South Branch Bear Run	3.3
Alder Run	0.7
Sandy Creek	2.8
Big Run	1
Deer Creek	5
Surveyor Run	4
Little Surveyor Run	2
Trout Run	5
Taylor Springs Run	0.4
Pine Run	2.2
Lick Run	3.7
Fork Run	3.8
Clearfield Creek	71.9
Sanbourne Run	2.2
North Branch Upper Morgan Run	2.7
Little Muddy Run	4.5

*Acid Mine Drainage Loadings*

Table 5.1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

Stream Name	Miles Degraded (based on length of study segment)
<b>Upper West Branch Susquehanna River Subbasin (cont'd)</b>	
Dutch Run	1.3
Brubaker Run	2
Birch Island Run	6.2
Little Birch Island Run	4.3
Amos Branch	1.6
<b>Upper West Branch Susquehanna River Subbasin</b>	
Sterling Run	9.7
Mosquito Creek	6
Curley's Run	1.2
Grimes Run	2
Moshannon Creek	1
Black Moshannon Creek	26.2
Cold Stream	1
Laurel Run	1
Goss Run	0.5
<b>Central West Branch Susquehanna River Subbasin</b>	
Pine Creek	4
Otter Run	3.8
Left Fork Otter Run	1.5
Right Fork Otter Run	0.4
Babb Creek	23
Wilson Creek	2.3
West branch Susquehanna R.	50.6
Lick Run	3.7
Tangascootack Creek	8.4
Drury Run (basin)	7.3
Stony Run	1.3
Woodley Draft Run	1.7
Sandy Run	1
Kettle Run	3
Two Mile Run	1.9

***Acid Mine Drainage Loadings***

Table 5.1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

<b>Stream Name</b>	<b>Miles Degraded (based on length of study segment)</b>
<b>Central West Branch Susquehanna River Subbasin (cont'd)</b>	
Hidden Branch Two Mile Run	2.1
Cooks Run (basin)	6.8
Crowley Hollow	3.1
Camp Run	2
Rock Run	1.2
Beech Creek (basin)	26
Middle Branch Big Run	5.5
East Branch Big Run	2.4
Logway Run	0.8
Northfork Beech Creek	5.9
<b>Lower West Branch Susquehanna River Subbasin</b>	
Red Run	13.4
West Branch Susquehanna R.	3
<b>Upper Juniata River Subbasin</b>	
Bear Loop Run	0.8
Beaver Dam Branch	2.3
Sugar Run	6.3
Burgoon Run	3
Kittanning Run	4.2
Glenwhite Run	3.2
Shoup Run	4.7
Miller Run	1.4
Hartman Run	0.6
Six Mile Run	3.5
Sandy Run	2.9
Longs Run	2.5
Kimber Run	2.7

Table 5.1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

North Branch Potomac River Subbasin	
Gladdens Run	11.8
Stony River	24.5
North Branch Potomac River	50
Slaughterhouse Run	2.17
Montgomery Run	2.81
Piney Swamp Run	5.51
Abram Creek	18.5
Emory Run	2.25
Glade Run	3.04
Little Creek	0.68
Deakin Run	1.15
Wills Creek	NA
Georges Creek	NA
Savage River	NA

Tables 5.2 - 5.4 summarize the cumulative acid mine drainage chemical contaminant loads in the tributaries of the Susquehanna River, the West Branch Susquehanna River, and the North Branch Potomac River.

## RECOMMENDATIONS

- ▶ Current water quality and discharge flow data are needed to support or revise the estimated loads presented. Recent mine drainage discharge data for the Anthracite Coal Fields were limited to a single sampling sweep of large discharges. Recent data for discharges in the West Branch Susquehanna River were not available during the preparation of this literature synthesis; however new data are being collected by watershed groups. When they become available, these new data will provide improved estimates of contaminant loading from coal mine drainage.
- ▶ Additional studies are needed to evaluate the transport of AMD chemical constituents (metals) from the upper reaches of the watershed to the Bay.
- ▶ Data correlating AMD loads in upper reaches of the Chesapeake Bay watershed with loadings of contaminants entering the Bay are lacking.

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Table 5.2. Summary of cumulative acid mine drainage chemical constituent loads in the Susquehanna River tributaries draining the anthracite coal fields in Pennsylvania. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow (cfs).

Tributary	Date	Flow	Condition	Sulfates	Iron	Manganese	Aluminum
<i>Northern Anthracite Coal Field</i>							
Lackawanna River  (in-stream at mouth)	1971-1972	156.4	Low	73,621	1,545		
	1971-1972	457.5	High	1,768,601	56,983		
	April 1975	218	High	621,688	30,263	4,859	309
	July 1982	75		125,578	3,569	835	158
	Oct. 1991	95.7	Low	183,166	9,964	1,251	
Susquehanna R discharges	April 1975	35.7	High	242,439	11,521		
	Oct. 1991	10.9	Low	44,284	2,357		
Solomon Creek (at mouth)	April 1975	66	High	488,003	53,658		
	July 1983	37	Normal	191,851	17,732	1,549	240
	Oct. 1991	25	Low	89,295			
Nanticoke Creek (at mouth)	April 1975	11	High	118,343	5,917		
	July 1982	3		16,042	717	118	33
<i>Eastern Middle Anthracite Coal Field</i>							
Nescopeck Creek (in-stream at mouth)	April 1975	89.9	High	168,924	2,412		
	July 1982	98		116,450	196	1,694	3,732
	Oct. 1991	26.2	Low	78,636	366	1,110	
Catawissa Creek (in-stream at mouth)	April 1975	36.6	High	34,446	260		
	August 1982	66		16,042	82	246	998
	October 1991	8.7	Low	11,139	59	139	

Table 5.2 (continued). Summary of cumulative acid mine drainage chemical constituent loads in the Susquehanna River tributaries draining the anthracite coal fields in Pennsylvania. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow (cfs).

<b>Tributary</b>	<b>Date</b>	<b>Flow</b>	<b>Condition</b>	<b>Sulfates</b>	<b>Iron</b>	<b>Manganese</b>	<b>Aluminum</b>
<i>Western Middle Anthracite Coal Field</i>							
Shamokin Creek (2.7 mi. from mouth)	1969-1970	65	Year Avg.		18,100		
	April 1975	64.7	High	188,182	17,846		
	July 1985	62.4		97,740	1,011	1,180	576
	Oct.-Nov. 1991	25.6	Low	54,169	4,576	589	
Mahanoy Creek (at mouth)	1973-1974	311	Year Avg.	761,178	15,582		
	April 1975	145	High	677,617	23,093		
	July 1985	121.4		208,082	2,083	2,017	385
	Oct.-Nov. 1991	51.4	Low	173,340	6,815	2,143	
<i>Southern Anthracite Coal Field</i>							
Swatara Creek (in-stream near Ravine)	April 1975	21.3	High	19,684	656		
	July 1985	20.8		18,050	115	212	16
	Oct. 1991	3.4	Low	2,443	98	35	
Wiconisco Creek (in-stream at mouth)	1973		Year Avg.	15,250	575		
	April 1975	20.6	High	27,584	2,098		
	July 1985	33.5		11,556	73	1	6
	Oct. 1991	2.7	Low	1,764	249	35	
Rausch Creek	1968-1969		Year Avg.	25,850	3,050		
	April 1975	13	High	16,858	1,900		
	Oct. 1991	4	Low	7,179	582	119	
Mahantango Creek (in-stream near mouth)	July 1985	37.7		7,315	300	18	230

Table 5.3. Summary of cumulative acid mine drainage chemical constituent loads in the West Branch Susquehanna River tributaries draining the bituminous coal fields in Pennsylvania. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow.

<b>Tributary</b>	<b>Date</b>	<b>Flow</b>	<b>Condition</b>	<b>Sulfates</b>	<b>Iron</b>	<b>Manganese</b>	<b>Aluminum</b>	<b>Zinc</b>
Headwaters Area Bakerton to Bower (in-stream at Bower)	1971	129	Year Avg.	159,447	400			
Anderson Creek	1973-1974	78.4	Year Avg.	23,559	365			
	May 1984	247	High	76,044	1,267	1,601	1,601	107
	July 1984	48	Low	22,555	75	544	467	31
Tributaries between Anderson Creek and Clearfield Creek	May 1984	359	High	155,252	2,727	3,969	2,761	219
	July 1984	27	Low	60,473	868	1,646	680	52
Clearfield Creek	1971			237,654	292			
	May 1984	1,670	High	1,262,805	39,688	15,334	20,746	992
	July 1984	230	Low	33,542	1,068	4,596	2,981	186
Tributaries between Clearfield Cr. and Moshannon Cr.	May 1984	598	High	472,096	7,058	12,671	9,418	1,005
	July 1984	104	Low	237,810	2,009	4,551	3,290	176
Moshannon Creek	1971			240,413	52,412			
	May 1984	1,160	High	939,812	28,194	13,784	21,929	877
	July 1984	192	Low	373,332	3,215	5,496	25,926	290
Tributaries between Moshannon Cr. and Sinnemahoning Cr.	May 1984	430	High	160,113	1,396	3,064	1,973	244
	July 1984	69	Low	94,003	225	1,686	643	75
Sinnemahoning Creek	May 1984	3,370	High	436,851	5,825	2,730	9,109	364
	July 1984	331	Low	87,602	322	483	179	36

Table 5.3 (continued). Summary of cumulative acid mine drainage chemical constituent loads in the West Branch Susquehanna River tributaries draining the bituminous coal fields in Pennsylvania. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow.

<b>Tributary</b>	<b>Date</b>	<b>Flow</b>	<b>Condition</b>	<b>Sulfates</b>	<b>Iron</b>	<b>Manganese</b>	<b>Aluminum</b>	<b>Zinc</b>
Cooks Run	1971	16	Year Avg.	9,936	899			
	May 1984	48	High	20,741	959	239	1,037	29
	July 1984	36	Low	31,111	1,225	408	972	41
Kettle Creek	May 1984	694	High	78,717	2,474	1,012	2,624	150
	July 1984	269	Low	104,611	3,487	2,179	2,615	131
Drury Run	1971	23.4	Year Avg.	4,720	286			
	May 1984	34	High	18,181	40	569	422	28
	July 1984	30	Low	29,167	32	972	567	36
	1990	21	Year Avg.	12,543	11	331	270	15.5
Tangascootac Creek	1984	22	Year Avg.	11,012	32	262	131	
Pine Creek (Contribution from Babb Creek)	1975-1976	192	Year Avg.	113,497	288			
(Contribution from Little Pine Creek)	1970-1971		Year Avg.	19,382	169			
Loyalsock Creek (in-stream downstream from all AMD sources)	1975		Year Avg.	14,999	450			
Tioga River (in-stream near Tioga Junction)	1992	444	Year Avg.	92,785	547	1,224	598	101
	1994	544	Year Avg.	97,649	1,516	1,913	1,958	181



Table 5.4. Summary of cumulative acid mine drainage chemical constituent loads in the North Branch Potomac River tributaries draining the bituminous coal fields in Maryland and West Virginia. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow (cfs).

<b>Tributary</b>	<b>Date</b>	<b>Flow</b>	<b>Condition</b>	<b>Sulfates</b>	<b>Iron</b>	<b>Manganese</b>	<b>Aluminum</b>	<b>Zinc</b>
Georges Creek	1972-1973	95.5	Year Avg.	143,913	1,444	1,135	1,702	
	1990-1991	96.9	Year Avg.	161,754	1,011	847	1,065	111
Braddock Run	1972-1973	34.4	Year Avg.	54,254	650	372	112	
Jennings Run	1972-1973	42.7	Year Avg.	28,137	115	46	185	
North Branch upstream from Jennings	1988-1989	73.1	Low	93,352	550	678	1,370	
Randolph Lake	1988-1989	974.3	High	412,115	3,472	2,474	5,226	

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## CHAPTER 6 - Fall Line Loadings

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### INTRODUCTION

The Chesapeake Bay Fall Line Toxics Monitoring Program (FLTMP) was established in the spring of 1990 as a pilot study to quantify annual loadings of trace metal and organic contaminants to the Bay from above the fall lines of the major tributaries. The fall line is the physiographic boundary in the eastern United States between the Piedmont and Atlantic Coastal Plain provinces, and as the natural geographic break between the tidal and non-tidal regions of the Bay watershed, the fall line is a convenient location to measure tributary fluxes of contaminants to the tidal Chesapeake Bay. Loadings above the river fall line represent an integration and interaction of upstream point and nonpoint sources of contaminants. Factors such as transport, retention, and attenuation of chemicals from upstream sources affect the loading at the fall line.

Trace contaminants monitored by the FLTMP have included twelve individual chemicals and polychlorinated biphenyls (PCBs) derived from the Chesapeake Bay Toxics of Concern list in addition to other related organonitrogen and organophosphorus (organo-N/P) pesticides, organochlorine insecticides (OCs), and polycyclic aromatic hydrocarbons (PAH). The goals of the FLTMP since its inception have been to (a) quantify the inputs of contaminants from the major tributaries to Chesapeake Bay, (b) assist water quality managers by determining the concentrations of contaminants in downstream waters of the tributary basins, and (c) characterize the hydrographic behavior of contaminants in fluvial transport at the fall lines of the major tributaries. In addition, riverine fluxes are being used in the development of a first-order mass balance model describing the inputs, transport, fate and cycling of contaminants within the Chesapeake Bay (Velinsky, 1997).

### TEMPORAL AND SPATIAL COVERAGE

Results from the 1990 and 1991 FLTMP have been reported previously in the *1994 Chesapeake Bay Basin Toxics Loadings and Release Inventory* and will not be provided herein. The FLTMP has continued from 1992 through 1997, and the tributaries monitored during this period are summarized in Table 6.1. Different tributaries have been examined in various years of the FLTMP to provide broad spatial coverage of the Bay basin and to allow for comparisons of loadings among the major tributary basins. Trace metal and organic contaminants analyzed through the FLTMP are listed in Tables 6.2 - 6.5 for each year from 1992 to 1997. Monitored

### ***Fall Line Loadings***

organic compounds have included chemicals present on the Toxics of Concern List as well as additional, structurally related contaminants. Many of the organonitrogen and organophosphorus pesticides represent high volume agrochemicals used throughout the Chesapeake Bay basin (Table 6.2). Monitored contaminants in the tributaries, including both inorganics and organic contaminants, have increased through the years because of greater capabilities available through the USGS, the University of Delaware, and the George Mason University Environmental Chemistry Laboratory. Loadings for all monitored organic contaminants have been included in this report.

Because trace contaminant transport is known to occur in both the dissolved and particulate phases, loadings in many cases are provided for both phases. Knowledge of the transport phase is relevant to understanding ultimate geochemical fate in Chesapeake Bay as well as more accurately defining the exposure of the Bay's living resources to contaminants.

Table 6.1. Summary of Chesapeake Bay Fall Line Toxics Monitoring Program sampling between 1992 and 1997.

<b>Calendar Year</b>	<b>Tributaries Monitored</b>	<b>Sampling Frequency</b>	<b>Constituents</b>
1992	Susquehanna, Potomac, and James	Monthly: Feb. - June Bimonthly: July - Jan. + major storms	metals + organics (USGS) <sup>a</sup>
1993	Susquehanna	2-3 times daily from 3/25/93 -4/3/93 and 11 times between 4/4/93 - 5/6/93 for high flow; biweekly from June - Dec.	metals only  (USGS)
1994	Susquehanna River  Susquehanna, Potomac, James, Patuxent, Choptank, Nanticoke, Pamunkey, Mattaponi, Rappahannock	Biweekly: Feb. - July Monthly: Aug.- Dec. + major storms  Spring and Fall synoptic	metals + organics  metals + organics (USGS, UDE, GMU)
1995	No fall line sampling	-	-
1996	Potomac		metals only (UDE)
1997	Chesterville Branch and Nanticoke	Bimonthly + two major storms	metals + organics (USGS, GMU)

<sup>a</sup>Agency coordinating contaminant sampling and analysis is indicated in parentheses: USGS, United States Geological Survey; UDE, University of Delaware; and GMU, George Mason University.

Table 6.2. List of organonitrogen and organophosphorus pesticides monitored at the fall line by year.

<b>Organonitrogen &amp; Organophosphorus Pesticides</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>
Simazine	X	ns	X	ns	ns
Prometon	X	ns	X	ns	ns
Atrazine	X	ns	X	ns	ns
Diazinon	X	ns	X	ns	ns
Alachlor	X	ns	X	ns	ns
Metolachlor		ns	X	ns	ns
Malathion	X	ns	X	ns	ns
Cyanazine	X	ns	X	ns	ns
Hexazinone	X	ns	X	ns	ns

X, constituent monitored; ns, not sampled.

Table 6.3. List of polycyclic aromatic hydrocarbons monitored at the fall line by year.

<b>Polycyclic Aromatic Hydrocarbons</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>
Naphthalene (Nap) <sup>a</sup>	X	ns	X	ns	ns
2-Methylnaphthalene (MN)		ns	X	ns	ns
2,6-Dimethylnaphthalene (DMN)		ns	X	ns	ns
Acenaphthylene (ACE)		ns	X	ns	ns
Acenaphthene (CAN)		ns	X	ns	ns
Fluorene (FLU)		ns	X	ns	ns
Phenanthrene (PHE)	X	ns	X	ns	ns
Fluoranthene (FLR)	X	ns	X	ns	ns
Pyrene (PYR)		ns	X	ns	ns
Benz[a]anthracene (BAA)	X	ns	X	ns	ns
Chrysene (CHR)		ns	X	ns	ns
Benzo[a]pyrene (BAP)		ns	X	ns	ns
Perylene (PER)		ns	X	ns	ns

<sup>a</sup> PAH abbreviations; X, constituent monitored; ns, not sampled.

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Table 6.4. List of organochlorine contaminants monitored at the fall line by year.

<b>Organochlorines</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>
alpha-HCH		ns	X	ns	ns
beta-HCH		ns	X	ns	ns
gamma-HCH		ns	X	ns	ns
Heptachlor		ns		ns	ns
Aldrin	X	ns	X	ns	ns
Heptachlor epoxide		ns		ns	ns
Oxychlordane	X	ns	X	ns	ns
trans-Chlordane	X	ns	X	ns	ns
Endosulfan I		ns		ns	ns
cis-Chlordane	X	ns	X	ns	ns
trans-Nonachlor		ns	X	ns	ns
Dieldrin	X	ns	X	ns	ns
p,p'-DDE		ns	X	ns	ns
o,p'-DDD		ns	X	ns	ns
Endrin		ns	X	ns	ns
p,p'-DDD		ns	X	ns	ns
o,p'-DDD		ns	X	ns	ns
p,p'-DDT	X	ns	X	ns	ns
Methoxychlor		ns	X	ns	ns
PCBs	116 CS	ns	116 CS	ns	ns
Hexachlorobenzene		ns	X	ns	ns
cis- and trans-Permethrin	X	ns		ns	ns

X, constituent monitored; ns, not sampled; CS, PCB congeners.

Table 6.5. List of trace metals monitored at the fall line by year.

TRACE METALS	1992	1993	1994	1995	1996
Al (dis)	X	X	X	ns	na
Al (par)			X	ns	na
As (dis)	X	X	X	ns	na
As (TR)	X	X		ns	na
Ba (TR)	X			ns	na
Cd (dis)	X	X	X	ns	na
Cd (par)			X	ns	na
Cd (TR)	X	X		ns	na
Cr (dis)	X	X	X	ns	na
Cr (par)			X	ns	na
Cr (TR)	X	X		ns	na
Cu (dis)	X	X	X	ns	na
Cu (par)			X	ns	na
Cu (TR)	X	X		ns	na
Fe (dis)	X	X	X	ns	na
Fe (par)			X	ns	na
Fe (TR)	X	X		ns	na
Pb (dis)	X	X	X	ns	na
Pb (par)			X	ns	na
Pb (TR)	X	X		ns	na
Li (TR)	X			ns	na
Mn (dis)			X	ns	na
Mn (par)			X	ns	na
Mn (TR)	X			ns	na
Hg (dis)	X	X		ns	na
Hg (par)				ns	na
Hg (TR)	X	X		ns	na
Ni (dis)	X	X	X	ns	na
Ni (par)			X	ns	na
Ni (TR)	X	X		ns	na
Se (TR)	X			ns	na
Ag (TR)	X			ns	na
Sr (dis)		X		ns	na
Sr (TR)	X	X		ns	na
Zn (dis)	X	X	X	ns	na
Zn (par)			X	ns	na
Zn (TR)	X	X		ns	na

X, constituent monitored; ns, not sampled; na, data not available.

## METHODOLOGY

Sampling was conducted along the fall lines of the Bay's three major tributaries (Figure 6.1) using ultra-clean sampling and analysis techniques for trace metal and organic contaminants in the river fall line samples. Thorough descriptions of sampling and analysis procedures may be found in other reports (CBP, 1994c; Foster and Lippa, 1996; Foster et al., in press).

Contaminant concentrations were used to estimate fall-line loadings in conjunction with stream flow data. All contaminant loads were estimated above the fall lines. Fluvial loadings above the fall lines were estimated for metals using a log-linear regression model (AMLE model) described by Cohen et al. (1991) or an Interpolation-Integration (I-I) method over a twelve month periods (Foster and Lippa, 1996). The AMLE model was preferred and used when data requirements were met, which happened only with metals data for select years. All organic contaminant data and some of the trace metal data were too sparse to meet the AMLE model requirements (Cohen et al., 1991), in which case the I-I model was used. The I-I method, which estimated baseflow ( $L_{BF}$ ) and stormflow ( $L_{SF}$ ) separately, is described by the equations below:

$$L_{bf} = F \sum_{j=1}^N c_j \sum_{i=-n_j}^{n_j} \bar{q}_{ij} t_{ij}$$
$$L_{sf} = F \sum_{l=1}^M \sum_{k=1}^{n_l} \bar{q}_{kl} c_{kl} t_{kl}$$

$F$  = conversion factor

$\bar{q}_{ij}$  = mean daily discharge ( $m^3/s$ ) on  $i$ th day of  $j$ th period (base flow)

$\bar{q}_{kl}$  = mean daily discharge ( $m^3/s$ ) on  $k$ th day of  $l$ th storm

$c_j$  = concentration (dissolved + particulate) of constituent ( $kg/m^3$ ) in  $j$ th period

$c_{kl}$  = concentration (dissolved + particulate) of constituent ( $kg/m^3$ ) on  $k$ th day of  $l$ th storm

$t_{ij}$  = hours of base flow on  $i$ th day of  $j$ th period

$t_{kl}$  = hours of storm flow on  $k$ th day of  $l$ th storm

$n_j$  = 0.5 number of days in  $j$ th period

$n_l$  = number of days per storm

$N$  = number of periods

$M$  = number of storms

Each daily load estimated using the I-I method was considered to be derived from baseflow, stormflow, or a combination of the two in which case daily  $L_{bf}$  and  $L_{sf}$  values were added together as partial daily loads for the beginning and ending days of the storm event. Estimated daily loads were summed throughout the study period to obtain annual (i.e., 12 month)

loads. Data censoring was employed in the I-I method whenever a contaminant was below the quantitation limit in the surface water samples. In these cases, separate maximum and minimum daily loads were estimated by adjusting the sample concentrations to the detection limits (maximum) in one scenario and to 0 (minimum) in the other. Loadings were estimated as load intervals when the differences between maximum and minimum estimates exceeded 10%. Mean daily stream discharges were obtained from the output of USGS gaging stations.

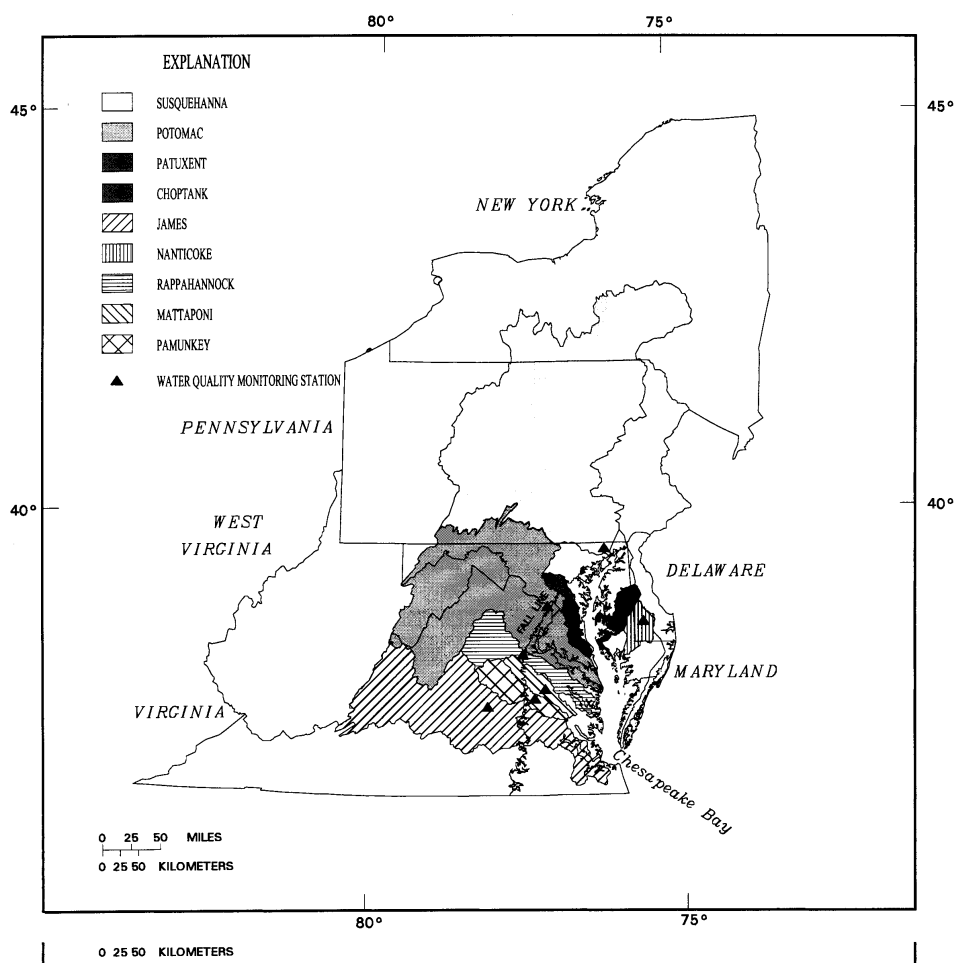


Figure 6.1. Map of Chesapeake Bay region showing nine watersheds monitored in 1994 synoptic study. (Map provided courtesy of the USGS in Baltimore, MD.)

## UNCERTAINTY

Estimates of contaminant loadings above the river fall lines are extremely dependent on river flows, which vary widely throughout the year. The FLTMP was designed to collect river water samples during baseflow and stormflow hydrologic conditions to obtain contaminant concentrations under wide ranges in flow. With the complexities of analyzing sub-parts-per-



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trillion concentrations of contaminants in water, sampling was limited to 25-40 collections per year. Therefore, the contaminant concentration data used to estimate annual loads was sparse, especially for organic contaminants, and the spatial and temporal variability of river fall line concentrations has not been systematically evaluated. The estimated fall line loads represent a first-order determination of contaminant fluxes in the monitored tributaries. The most accurate loadings exist for the Susquehanna River because the most intensive sampling effort has been carried out for this tributary.

Uncertainties in river fall line loading estimates have not been rigorously evaluated. The AMLE loading estimator provides model prediction errors for each constituent and has been the preferred method used in this study. However, the AMLE has a minimum threshold for concentration values (~60 measured concentrations for each constituent over a two year period) for loading estimates and has been highly dependent on the detection frequency of each monitored contaminant. Most organic contaminants and several metals have been measured at less frequency than the model threshold values. (The AMLE model is rarely used with organic contaminants because the organics data is very sparse and rarely has the FLTMP monitored organic contaminants in consecutive years, whereas metals are routinely monitored annually providing a larger basis set for the AMLE model.) Uncertainties determined for the I-I model are obtained through the analytical procedures. For example, for organic contaminant data the assigned uncertainties (first evaluated in the 1994 FLTMP) from propagated errors accumulated through the analytical method; it is assumed in this case that hydrologic uncertainties are insignificant and remain unknown. Uncertainties are also determined through the I-I model in the form of loading intervals. When a particular contaminant in a river fall line sample is below the analytical detection limit, the I-I model estimates two loads. The first is determined using the analytical detection limit of the contaminant (maximum value) and another using a concentration of zero. When the annual loads are compiled in the I-I model, an interval may exist for the maximum to the minimum values. Uncertainty estimates have not been standardized in the FLTMP and remain an important variable to be addressed in future studies.

## **DISCUSSION**

River fall line loading estimates are a function of many hydrologic, geochemical, and watershed variables, many of which have not been quantified or evaluated in the Chesapeake basin. For example, the seasonal application rates of agrochemicals in the Bay's drainage basins have been only crudely estimated from anecdotal information and for the most part are not known with any reasonable certainty. Fall line loadings of agrochemicals will be a function of seasonal application rates which must be better determined in the future. The temporal variability in river fall line contaminant concentrations at the fall line has not been well quantified, leaving sampling variability a virtually unknown uncertainty. In addition, the impact of large storms, annual precipitation, soil moisture, and urban influences are only understood in a general nature because little scientific data exists which describes or models fluvial transport dynamics. And finally, the influence of the airshed and atmospheric deposition on fall line loadings is unknown. Therefore, the fall line loading estimates provided to date by the FLTMP can only be viewed as preliminary, first-order flux values which provide very little in the way of

understanding the underlying mechanisms of transport. Other sources of information such as land use and point source delineations also need good documentation as sources of the various contaminants.

Loadings above the river fall lines represent an integration and interaction of all point and non-point source inputs upstream from the point of sampling. Major upstream contributors to the fall line loads cannot be determined without further systematic investigation; however, correlations have been developed between contaminants and sources. For example, the organonitrogen and organophosphorus pesticide inputs arise primarily from agricultural (e.g., atrazine and metolachlor) and urban (e.g., diazinon) sources, and the PAHs are derived primarily from urban sources where large amounts of pyrolysis by-products are formed through gas phase combustion. PCBs and organochlorine inputs have been less well characterized and are thought to come from contaminated industrial sites, long-term sequestration into agricultural and urban soils, and atmospheric deposition from global transport and cycling.

The most important variable influencing fall line loadings is river discharge because (a) river discharge was such a large loadings driver relative to the fall line contaminant concentrations in the loading estimation methods (given that the baseline river fall line contaminant concentrations were generally in the low parts per billion to low parts per trillion range), (b) and seasonal variability in river discharge in the major tributaries changed over a greater scale than river fall line contaminant concentrations. Annual loadings for the organic contaminants are listed in Tables 6.6 - 6.14 for the fall lines of the three major tributaries of the Bay (Susquehanna, Potomac, and James Rivers) for the various chemical classes (organonitrogen and organophosphorus pesticides, polycyclic aromatic hydrocarbons, and organochlorines). The largest loadings were observed for the current use agrochemicals (e.g., atrazine, metolachlor, and cyanazine) followed sequentially by the PAHs, PCBs, and organochlorine pesticides. The fall line loadings estimated for the three major tributaries for most of the contaminants were proportional to the land areas of each of the drainage basins. Thus, the Susquehanna River fallline showed the largest loadings followed by the Potomac and James Rivers.

Trace metal loads above the three major tributaries are listed in Tables 6.15 - 6.17. Aluminum had the greatest total annual load, followed by iron, then manganese. These results reflected the crustal abundances of these metals. The lowest total load occurred for cadmium although the loads for this element still appeared to be significantly higher than expected from crustal abundance.

Instantaneous loads for the organic contaminants and trace metals in the nine tributary synoptic study in 1994 are shown in Tables 6.18 - 6.25. Results of the spring tributary synoptic study showed that for all trace metals, with the exception of iron, the largest instantaneous loads were above the Susquehanna River fall line. However, the loads at the Potomac and James Rivers were greater than those for all of the other seven tributaries. These loads are, in part, the result of higher river flows measured at these three river sites than those at the other six tributaries. Organic contaminants followed the same trend, with the largest instantaneous loads

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occurring above the Susquehanna, Potomac, and James River fall lines.

## **CORRELATION WITH 1994 TOXICS LOADING AND RELEASE INVENTORY**

Organic contaminant loads reported in the 1994 TLRI included only atrazine (Susquehanna and James Rivers), metolachlor, and alachlor (Susquehanna River only). Analytical detection limits were insufficient to determine accurate loads for any other organic constituents in the 1990 and 1991 fall line toxics monitoring program. Average annual atrazine loads above the fall line of the Susquehanna River for 1990 and 1991 were found to be 4,000 kg, where as in 1992 and 1994, atrazine loads above the Susquehanna River fall line were estimated to be 1,700 kg and 2,970 kg, respectively. These loading estimates are all within a factor of 3, which is quite good considering the change in analytical methods and load estimation techniques during 1990-1994.

Variation in annual loads for all contaminants is most directly related to discharge above the fall line. The average annual river discharges measured at the Susquehanna River fall line (at Conowingo, MD) were 1,000 m<sup>3</sup>/s, 1,494 m<sup>3</sup>/s, 1,464 m<sup>3</sup>/s for 1992, 1993, and 1994, respectively. The generally higher loadings estimated for organic and metal contaminants in 1994 in comparison to 1992, for example, can be attributed primarily to higher discharge in 1994 recorded at the Susquehanna River fall line.

There are other factors which account for the annual variability seen in the fall line load estimates. Changes in analytical methodology, hydrographic and sampling variability, and changes in watershed characteristics all affect fall line loadings. None of these factors has been previously evaluated.

## **RECOMMENDATIONS**

Contaminant loadings above the fall lines of the major northern and western shore tributaries have been estimated for organics and metals between 1990-1994. We now have a picture of the magnitudes of contaminant loadings to Chesapeake Bay from the major tributaries. The fall line monitoring program has fulfilled the objectives of the pilot phase, which has been to provide preliminary loading estimates for contaminants to the Bay from the rivers. Future work should be devoted to refining the loading estimates for contaminants in the next phase of the program: to be able to compare loadings estimated among the various sources. To accomplish an accurate mass budget and preliminary model development for quantifying input of contaminants to Chesapeake Bay, refined estimates of the uncertainties of loadings via the tributaries are needed. To address this issue the following recommendations are put forward:

- ▶ Better define contaminant behavior above the fall lines in the watersheds. There needs to be more mechanistic orientation of how contaminants enter and are transported in rivers.
- ▶ Include the influence of the air shed in fall line loadings. We need to better understand

source dynamics in the watershed. Where do the contaminants ultimately come from? Do they originate from contaminated soils, urban runoff, or atmospheric deposition? These questions need to be addressed to move into the modeling phase of contaminant transport in the Bay watershed.

- ▶ Better define the uncertainties in the magnitudes of the fall line load estimates. The Susquehanna and/or Potomac Rivers should be used as model basins to more precisely define the factors which affect the loading estimates and to systematically quantify the uncertainties in loadings estimates.
- ▶ Better link the contaminant release information with fall line loadings. For example, contaminant release data should support the fall line loading estimates by determining pesticide application rates within river basins rather than within the states or counties.
- ▶ To more fully understand the effects of extremely high flow events in the major tributaries. Many contaminants are stored in sediments up in the watersheds, and extremely high flow events may promote the transport of these contaminants to the Bay in very large quantities over short time frames. These low frequency events may have profound implications to the biological effects of contaminants in the Bay.
- ▶ Establish one or more long-term contaminant-loading stations. We have established that the majority of the loadings occur through the rivers if we look at the nutrient model. Long-term data is essential for resolving management issues. We recommend that each state in the watershed select one site, such as:
  - PA - Conowingo Dam (Susquehanna River)
  - Washington, D.C. - Chain Bridge (Potomac River)
  - VA - Cartersville (James River)
  - MD - Choptank or Nanticoke Rivers (Eastern Shore)We recommend combining funds from EPA, USGS, and the states to start long-term monitoring using our low-level techniques.

***Fall Line Loadings***

Table 6.6. Annual loads (kg/yr) of organonitrogen and organophosphorus pesticides above the fall line (AFL) of the Susquehanna River.

<b>Organonitrogen &amp; Organophosphorus Pesticides</b>	<b>Estimation Method</b>	<b>3/92-2/93 AFL</b>	<b>2/93-1/94 AFL</b>	<b>2/94-1/95 AFL</b>
Simazine	I-I	580-610	-	2010-2020
Prometon	I-I	110-160	-	1030
Atrazine	I-I	1700	-	2970
Diazinon	I-I	8-98	-	220-260
Alachlor	I-I	97-106	-	710
Metolachlor	I-I	920	-	2450
Malathion	I-I	8-86	-	20-180
Cyanazine	I-I	430-480	-	3010
Hexazinone	I-I	170-180	-	130-250

Table 6.7. Annual loads (kg/yr) of organonitrogen and organophosphorus pesticides above the fall line (AFL) of the Potomac River.

<b>Organonitrogen &amp; Organophosphorus Pesticides</b>	<b>Estimation Method</b>	<b>3/92-2/93 AFL</b>	<b>2/93-1/94 AFL</b>	<b>2/94-1/95 AFL</b>
Simazine	I-I	340	-	-
Prometon	I-I	56-66	-	-
Atrazine	I-I	780	-	-
Diazinon	I-I	3-27	-	-
Alachlor	I-I	25-44	-	-
Metolachlor	I-I	390	-	-
Malathion	I-I	3-25	-	-
Cyanazine	I-I	220-230	-	-
Hexazinone	I-I	6-14	-	-
cis- and trans-Fenvalerate	I-I	-	-	-
cis- and trans-Permethrin	I-I	-	-	-

Table 6.8. Annual loads (kg/yr) of organonitrogen and organophosphorus pesticides above the fall line (AFL) of the James River.

<b>Organonitrogen &amp; Organophosphorus Pesticides</b>	<b>Estimation Method</b>	<b>3/92-2/93 AFL</b>	<b>2/93-1/94 AFL</b>	<b>2/94-1/95 AFL</b>
Simazine	I-I	130-140	-	-
Prometon	I-I	18-26	-	-
Atrazine	I-I	220	-	-
Diazinon	I-I	20-30	-	-
Alachlor	I-I	15-28	-	-
Metolachlor	I-I	89-92	-	-
Malathion	I-I	3-18	-	-
Cyanazine	I-I	32-43	-	-
Hexazinone	I-I	18-26	-	-

Table 6.9. Annual loads (kg/yr) of polycyclic aromatic hydrocarbons above the fall line (AFL) of the Susquehanna River.

<b>Polycyclic Aromatic Hydrocarbon</b>	<b>Estimation Method</b>	<b>3/92-2/93 AFL</b>	<b>2/93-1/94 AFL</b>	<b>2/94-1/95 AFL</b>
Naphthalene	I-I	300	-	-
2-Methylnaphthalene	I-I	-	-	220
2,6-Dimethylnaphthalene	I-I	-	-	140
Acenaphthylene	I-I	-	-	50
Acenaphthene	I-I	-	-	57
Fluorene	I-I	-	-	120
Phenanthrene	I-I	98-120	-	450
Fluoranthene	I-I	-	-	1130
Pyrene	I-I	-	-	1030
Benz[a]anthracene	I-I	55-120	-	380
Chrysene	I-I	-	-	330
Benzo[a]pyrene	I-I	14-120	-	440
Perylene	I-I	-	-	480

***Fall Line Loadings***

Table 6.10. Annual loads (kg/yr) of polycyclic aromatic hydrocarbons above the fall line (AFL) of the Potomac River.

<b>Polycyclic Aromatic Hydrocarbon</b>	<b>Estimation Method</b>	<b>3/92-2/93 AFL</b>	<b>2/93-1/94 AFL</b>	<b>2/94-1/95 AFL</b>
Naphthalene	I-I	60-75	-	-
2-Methylnaphthalene	I-I	-	-	-
2,6-Dimethylnaphthalene	I-I	-	-	-
Acenaphthylene	I-I	-	-	-
Acenaphthene	I-I	-	-	-
Fluorene	I-I	-	-	-
Phenanthrene	I-I	19-23	-	-
Fluoranthene	I-I	-	-	-
Pyrene	I-I	-	-	-
Benz[a]anthracene	I-I	29-48	-	-
Chrysene	I-I	-	-	-
Benzo[a]pyrene	I-I	11-49	-	-
Perylene	I-I	-	-	-

Table 6.11. Annual loads (kg/yr) of polycyclic aromatic hydrocarbons above the fall line (AFL) of the James River.

<b>Polycyclic Aromatic Hydrocarbon</b>	<b>Estimation Method</b>	<b>3/92-2/93 AFL</b>	<b>2/93-1/94 AFL</b>	<b>2/94-1/95 AFL</b>
Naphthalene	I-I	43-67	-	-
2-Methylnaphthalene	I-I	-	-	-
2,6-Dimethylnaphthalene	I-I	-	-	-
Acenaphthylene	I-I	-	-	-
Acenaphthene	I-I	-	-	-
Fluorene	I-I	-	-	-
Phenanthrene	I-I	140	-	-
Fluoranthene	I-I	-	-	-
Pyrene	I-I	-	-	-
Benz[a]anthracene	I-I	26-35	-	-
Chrysene	I-I	-	-	-
Benzo[a]pyrene	I-I	61-82	-	-
Perylene	I-I	-	-	-

Table 6.12. Annual loads (kg/yr) of organochlorines above the fall line (AFL) of the Susquehanna River.

<b>Organochlorines</b>	<b>Estimation Method</b>	<b>3/92-2/93 AFL</b>	<b>2/93-1/94 AFL</b>	<b>2/94-1/95 AFL</b>
alpha-HCH	I-I	-	-	11
beta-HCH	I-I	-	-	6
gamma-HCH	I-I	-	-	18
Oxychlordane	I-I	26-32	-	10
trans-Chlordane	I-I	11-17	-	12
cis-Chlordane	I-I	21-28	-	6
trans-Nonachlor	I-I	-	-	13
Dieldrin	I-I	7-14	-	12
p,p'-DDE	I-I	-	-	16
o,p'-DDD	I-I	-	-	20
Endrin	I-I	-	-	4-11
p,p'-DDD	I-I	-	-	13
p,p'-DDT	I-I	6-29	-	12
Methoxychlor	I-I	-	-	1-8
PCBs	I-I	170-198	-	160-190
Hexachlorobenzene	I-I	-	-	4
cis- and trans-Fenvalerate	I-I	14-44	-	-
cis- and trans-Permethrin	I-I	4-95	-	-



***Fall Line Loadings***

Table 6.13. Annual loads (kg/yr) of organochlorines above the fall line (AFL) of the Potomac River.

<b>Organochlorines</b>	<b>Estimation Method</b>	<b>3/92-2/93 AFL</b>	<b>2/93-1/94 AFL</b>	<b>2/94-1/95 AFL</b>
alpha-HCH	I-I	-	-	-
beta-HCH	I-I	-	-	-
gamma-HCH	I-I	-	-	-
Oxychlordane	I-I	14-15	-	-
trans-Chlordane	I-I	4-6	-	-
cis-Chlordane	I-I	13-15	-	-
trans-Nonachlor	I-I	-	-	-
Dieldrin	I-I	13-15	-	-
p,p'-DDE	I-I	-	-	-
o,p'-DDD	I-I	-	-	-
Endrin	I-I	-	-	-
p,p'-DDD	I-I	-	-	-
p,p'-DDT	I-I	3-10	-	-
Methoxychlor	I-I	-	-	-
PCBs	I-I	22-48	-	-
Hexachlorobenzene	I-I	-	-	-
cis- and trans-Fenvalerate	I-I	-	-	-
cis- and trans-Permethrin	I-I	-	-	-

Table 6.14. Annual loads (kg/yr) of organochlorines above the fall line (AFL) of the James River.

<b>Organochlorines</b>	<b>Estimation Method</b>	<b>3/92-2/93 AFL</b>	<b>2/93-1/94 AFL</b>	<b>2/94-1/95 AFL</b>
alpha-HCH	I-I	-	-	-
beta-HCH	I-I	-	-	-
gamma-HCH	I-I	-	-	-
Oxychlordane	I-I	6-10	-	-
trans-Chlordane	I-I	11-12	-	-
cis-Chlordane	I-I	16-19	-	-
trans-Nonachlor	I-i	-	-	-
Dieldrin	I-I	3-4	-	-
p,p'-DDE	I-I	-	-	-
o,p'-DDD	I-I	-	-	-
Endrin	I-I	-	-	-
p,p'-DDD	I-I	-	-	-
p,p'-DDT	I-I	0.1-6	-	-
Methoxychlor	I-I	-	-	-
PCBs	I-I	18-32	-	-
Hexachlorobenzene	I-I	-	-	-
cis- and trans-Fenvalerate	I-I	-	-	-
cis- and trans-Permethrin	I-I	-	-	-

**Fall Line Loadings**

Table 6.15. Annual loads (metric tons per year) of trace metals above the fall line (AFL) of the Susquehanna River.

Trace Metals	Estim. Method 1992	Loads 3/92-2/93 AFL <sup>a</sup>	Estim. Method 1993	Loads 2/93-1/94 AFL <sup>a</sup>	Estim. Method 1994	Loads 2/94-1/95 AFL <sup>b</sup>
Al	AMLE	828-994	AMLE	1,111-1,388	II	67,400
As	II	0-32	II	12-49		-
Cd	II	0-32	II	0-46	II	29
Cr	II	64-74	II	80-94	II	115-116
Cu	AMLE	60-71	AMLE	111-135	II	199
Fe	AMLE	17-29	AMLE	76,448-	II	44,100
Pb	AMLE	42-53	AMLE	119-163	II	45
Mn		-		-	II	4,830
Hg	II	0.3-3		-		-
Ni	AMLE	147-190		-	II	186
Zn	AMLE	349-453	AMLE	992-1,314	II	438

<sup>a</sup>Loads determined from total recoverable concentrations except for Al loads for 1992 and 1993 in which they were determined from dissolved (only) concentrations.

<sup>b</sup>Loads determined from the sum of dissolved and particulate concentrations.

Table 6.16. Annual loads (kg/yr X 10<sup>-3</sup>) of trace metals above the fall line (AFL) of the Potomac River.

Trace Metals	Estim. Method 1992	Loads 3/92-2/93 AFL <sup>a</sup>	Estim. Method 1993	Loads 2/93-1/94 AFL	Estim. Method 1994	Loads 2/94-1/95 AFL
Al		-		-		-
As	II	0-58		-		-
Cd	II	0-19		-		-
Cr	II	31-50		-		-
Cu	II	44-60		-		-
Fe (dissolved only)	II	-		-		-
Pb	II	41-77		-		-
Mn		-		-		-
Hg		-		-		-
Se	II	0-76				
Ni	II	60-167		-		-
Zn	II	241-327		-		-

<sup>a</sup>Loads determined from total recoverable concentrations.

Table 6.17. Annual loads (metric tons per year) of trace metals above the fall line (AFL) of the James River.

Trace Metals	Estim. Method 1992	Loads 3/92-2/93 AFL <sup>a</sup>	Estim. Method 1993	Loads 2/93-1/94 AFL	Estim. Method 1994	Loads 2/94-1/95 AFL
Al	AMLE	729-949		-		-
As	II	0-4		-		-
Cd	II	0-6		-		-
Cr	AMLE	31-44		-		-
Cu	AMLE	22-28		-		-
Fe (dissolved only)	AMLE	1,490-1,940		-		-
Pb	AMLE	24-34		-		-
Mn		-		-		-
Hg	II	0.02-0.6		-		-
Ni	AMLE	25-38		-		-
Zn	AMLE	93-118		-		-

<sup>a</sup>Loads determined from total recoverable concentrations except for Al which was determined from dissolved (only) concentrations.

Table 6.18. Instantaneous loads (mg/s) of organonitrogen and organophosphorus pesticides above the fall lines or head of tide of the nine major tributaries of Chesapeake Bay from March 26 through May 5, 1994.

	Pam	Mat	Jam	Rap	Pot	Chop	Nant	Pat	Sus
Simazine	0.50	0.010	2.40	0.58	18.2	0.81	0.82	0.005	154
Prometon	0.17	0.083	0.52	0.27	4.31	0.18	0.085	0.005	13.8
Atrazine	0.51	0.12	1.02	0.61	17.8	2.98	0.24	0.004	172
Alachlor	0.009	0.051	0.064	0.016	0.90	0.15	0.13	0.003	8.46
Metolachlor	0.056	0.005	0.045	0.011	5.40	0.84	0.041	0.002	39.9
Cyanazine	0.020	0.016	0.14	0.036	1.93	0.11	0.017	0.007	1.43
Hexazinone	0.38	0.29	0.52	0.66	28.8	2.14	0.37	0.002	174

***Fall Line Loadings***

Table 6.19. Instantaneous loads (mg/s) of organonitrogen and organophosphorus pesticides above the fall lines or head of tide for the nine major tributaries of Chesapeake Bay from November 8 through November 18, 1994.

	<b>Pam</b>	<b>Mat</b>	<b>Jam</b>	<b>Rap</b>	<b>Pot</b>	<b>Chop</b>	<b>Nant</b>	<b>Pat</b>	<b>Sus</b>
Simazine	0.209	0.30	0.59	0.51	3.67	0.031	0.019	0.27	0.077
Prometon	0.049	0.031	0.32	0.088	1.38	0.008	0.009	0.076	1.37
Atrazine	0.085	0.055	0.15	0.25	3.20	0.013	0.011	0.26	4.51
Alachlor	0.007	0.002	0.034	0.007	0.047	0.000	0.001	0.095	0.27
Metolachlor	0.002	0.001	0.013	0.003	0.107	0.005	0.045	0.015	0.65
Cyanazine	0.054	0.005	0.040	0.011	0.057	0.001	0.001	0.003	0.81
Hexazinone	0.028	0.017	0.061	0.22	1.35	0.026	0.047	0.19	2.83

Table 6.20. Instantaneous loads (mg/s) of polycyclic aromatic hydrocarbons above the fall line or head of tide of the nine major tributaries of Chesapeake Bay from March 26 through May 5, 1994.

	<b>Pam</b>	<b>Mat</b>	<b>Jam</b>	<b>Rap</b>	<b>Pot</b>	<b>Chop</b>	<b>Nant</b>	<b>Pat</b>	<b>Sus</b>
MN <sup>a</sup>	0.12	0.076	18.9	0.011	24.3	1.13	0.15	0.002	85.2
DMN	0.31	0.015	0.67	0.028	0.74	0.014	0.011	0.007	1.43
ACE	0.037	0.012	0.23	0.023	1.18	0.008	0.004	0.000	5.84
CAN	0.020	0.002	0.46	0.056	6.09	0.004	0.007	0.007	9.93
FLU	0.003	0.003	0.080	0.003	0.74	0.002	0.002	0.001	1.30
PHEN	0.005	0.006	0.25	0.003	0.56	0.011	0.004	0.001	1.52
FLR	0.011	0.008	0.32	0.018	1.39	0.010	0.005	0.003	3.66
PYR	0.028	0.032	0.68	0.051	3.70	0.023	0.010	0.027	10.2
CHR	0.025	0.019	0.76	0.030	13.2	0.013	0.018	0.11	56.1
BAA	0.014	0.009	0.49	0.015	9.46	0.008	0.017	0.091	42.9
BAP	0.001	0.001	0.26	0.003	4.49	0.000	0.001	0.032	6.95
PER	0.001	0.001	0.18	0.001	3.15	0.000	0.001	0.032	7.31

<sup>a</sup> Refer to Table 3 for PAH abbreviations.

### *Fall Line Loadings*

Table 6.21. Instantaneous loads (mg/s) of polycyclic aromatic hydrocarbons above the fall line or head of tide of the nine major tributaries of Chesapeake Bay from November 8 through November 18, 1994.

	<b>Pam</b>	<b>Mat</b>	<b>Jam</b>	<b>Rap</b>	<b>Pot</b>	<b>Chop</b>	<b>Nant</b>	<b>Pat</b>	<b>Sus</b>
MN	0.002	0.001	5.69	0.003	6.12	<0.001	<0.001	0.001	7.005
DMN	0.12	0.053	0.33	0.009	0.14	0.003	0.003	0.041	0.120
ACE	0.018	0.013	0.26	0.034	0.20	0.006	0.003	0.020	0.598
ACN	<0.001	<0.001	0.005	0.001	0.11	0.007	<0.001	0.001	0.312
FLU	0.008	0.003	0.028	0.004	0.079	0.001	0.001	0.009	0.136
PHEN	0.002	0.001	0.001	0.001	0.043	<0.001	<0.001	<0.001	0.078
FLR	<0.001	<0.001	<0.001	<0.001	0.010	<0.001	<0.001	0.001	0.292
PYR	0.019	0.006	0.088	0.005	0.27	0.001	<0.001	0.017	0.807
CHR	0.016	0.007	0.093	0.005	0.45	0.001	0.001	0.033	1.548
BAA	<0.001	<0.001	0.021	<0.001	0.24	<0.001	<0.001	0.020	1.384
BAP	<0.001	0.003	0.052	0.001	0.29	0.001	0.001	0.019	0.679
PER	<0.001	<0.001	0.009	<0.001	0.11	<0.001	<0.001	0.007	0.820

Table 6.22. Instantaneous loads (mg/s) of organochlorines above the fall line or head of tide of the nine major tributaries of Chesapeake Bay from March 26 through May 5, 1994.

	<b>Pam</b>	<b>Mat</b>	<b>Jam</b>	<b>Rap</b>	<b>Pot</b>	<b>Chop</b>	<b>Nant</b>	<b>Pat</b>	<b>Sus</b>
PCBs	0.0002	0.0002	0.37	0.0004	6.13	0.0001	0.0001	0.057	5.04
HCB	0.0870	0.19	0.42	0.0012	5.56	0.0043	0.0001	0.037	7.27
p,p'-DDE	0.0399	0.0047	0.31	0.0435	1.62	0.0048	0.0026	0.013	3.07
p,p'-DDT	0.0024	0.0001	0.015	0.0017	0.084	0.0002	0.0001	0.0001	0.017
$\alpha$ -BHC	0.0002	0.0002	0.0068	0.0045	0.25	0.0021	0.0024	0.0013	0.311
$\beta$ -BHC	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4
$\gamma$ -BHC	0.0005	0.0009	0.0061	0.0067	0.0658	0.0010	0.0009	0.0002	0.311
Oxychlor	0.0018	0.0015	0.0060	0.0092	0.0408	0.0003	0.0002	0.0011	0.19
$\gamma$ -Chlordane	0.0025	0.0032	0.038	0.014	0.1793	0.0016	0.0043	0.0002	0.97
$\alpha$ -Chlordane	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4
t-Nonachlor	0.0002	0.0002	0.0087	0.0078	0.14	0.0009	0.0009	0.0014	0.052
Dieldrin	0.0015	0.0005	0.0041	0.0024	0.0056	0.0002	0.0004	0.0001	0.0156
o,p'-DDD	0.0002	0.0002	0.0017	0.0021	0.0128	0.0001	0.0002	0.0012	0.0345
Endrin	0.0023	0.0006	0.0170	0.0066	0.033	0.0030	0.0002	0.0020	0.1036
p,p'-DDD	0.0007	0.0004	0.0034	0.0021	0.138	0.0001	0.0003	0.0040	0.225

**Fall Line Loadings**

Table 6.23. Instantaneous loads (mg/s) of organochlorines above the fall line or head of tide of the nine major tributaries of Chesapeake Bay from November 8 through November 18, 1994.

	<b>Pam</b>	<b>Mat</b>	<b>Jam</b>	<b>Rap</b>	<b>Pot</b>	<b>Chop</b>	<b>Nant</b>	<b>Pat</b>	<b>Sus</b>
PCBs	<1e-4	<1e-4	0.0005	0.0001	0.093	<1e-4	<1e-4	0.0080	1.2
HCB	0.039	0.048	0.22	0.062	0.17	0.0081	0.0050	0.020	2.2
p,p'-DDE	0.0074	0.0030	0.12	0.044	0.045	0.0005	0.0002	0.0020	0.32
p,p'-DDT	<1e-4	<1e-4	0.0025	0.0007	0.0041	<1e-4	<1e-4	<1e-4	0.0072
$\alpha$ -BHC	<1e-4	<1e-4	0.0005	0.0001	0.0012	0.0002	<1e-4	0.0002	0.046
$\beta$ -BHC	<1e-4	<1e-4	<1e-4	0.0003	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4
$\gamma$ -BHC	0.0001	0.0019	0.018	0.0045	0.0068	<1e-4	<1e-4	0.0008	0.035
Oxychlor	0.0008	0.0018	0.022	0.0039	0.0019	<1e-4	0.0002	0.0005	0.0087
$\gamma$ -Chlordane	0.0001	0.0011	0.026	0.0028	0.023	<1e-4	<1e-4	0.0083	0.062
$\alpha$ -Chlordane	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4
t-Nonachlor	<1e-4	0.0003	0.0039	0.0010	0.013	<1e-4	<1e-4	0.0006	0.010
Dieldrin	<1e-4	<1e-4	0.0013	<1e-4	0.0006	<1e-4	<1e-4	0.0002	0.0013
o,p'-DDD	<1e-4	<1e-4	0.0005	0.0001	0.0007	<1e-4	<1e-4	0.0004	0.0014
Endrin	<1e-4	0.0004	0.0046	0.0007	0.0102	<1e-4	<1e-4	0.0003	0.0043
p,p'-DDD	0.0001	0.0005	0.0069	0.0002	0.016	<1e-4	0.0001	0.0004	0.0072

Table 6.24. Instantaneous loads (mg/s) of trace metals above the fall line or head of tide of the nine major tributaries of Chesapeake Bay from March 26 through May 5, 1994.

	<b>Pam</b>	<b>Mat</b>	<b>Jam</b>	<b>Rap</b>	<b>Pot</b>	<b>Chop</b>	<b>Nant</b>	<b>Pat</b>	<b>Sus</b>
Al	3350	4630	23000	3780	210000	1650	806	3700	336000
Cd	4.8	1.4	12.9	0.94	29.9	0.36	1.4	1.3	242
Cr	10.5	17.5	197	19.1	1200	5.8	3.3	21.5	9590
Cu	59.1	15.2	326	36.1	1620	11.2	9.8	22.2	4090
Fe	14500	31800	28300	7980	236000	8050	3400	6810	88700
Mn	667	1270	1430	290	13300	819	222	614	102000
Ni	1.46	15.2	105	0.12	1130	15.1	17.0	21.6	4350
Pb	10	11.3	20.5	8.20	81.4	2.9	1.2	4.5	395
Zn	122	72.1	367	22.1	2972	44.2	103	58.8	19800

Table 6.25. Instantaneous loads (mg/s) of total trace metals above the fall line or head of tide of the nine major tributaries of Chesapeake Bay from November 8 through November 18, 1994.

	<b>Pam</b>	<b>Mat</b>	<b>Jam</b>	<b>Rap</b>	<b>Pot</b>	<b>Chop</b>	<b>Nant</b>	<b>Pat</b>	<b>Sus</b>
Al	3860	548	966	390	17800	14.6	46.6	186	126000
Cd	na <sup>a</sup>	0.74	4.19	0.51	5.57	0.11	0.22	0.56	929
Cr	2.95	3.22	21.4	2.84	68.9	0.26	1.00	1.97	4550
Cu	12.8	3.88	22.6	8.29	72.2	0.15	0.24	2.75	2180
Fe	6350	5980	6100	1130	12400	548	161	1420	651000
Mn	550	175	313	40.4	648	11.9	13.4	381	94300
Ni	9.19	5.85	37.5	7.55	64.4	0.93	2.12	5.85	3230
Pb	2.71- 2.92	2.45	3.05- 4.51	1.28	10.7	0.02- 0.05	0.00- 0.04	0.45	1270
Zn	67.6	10.6	24.2- 25.1	7.92	115	0.94	18.7	20.6	5670

<sup>a</sup>not available



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## **CHAPTER 7 - Pesticide Usage and Occurrence in Surface and Ground Water**

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### **INTRODUCTION**

The use of pesticides for agricultural and non-agricultural purposes and the potential for these chemicals to adversely affect both surface and ground water as well as the Bay's living resources is a concern of the Chesapeake Bay Program. Although the use of pesticides is a necessary aspect of pest control, Integrated Pest Management (IPM) techniques can be utilized to potentially reduce the use of pesticides and possible risks associated with these chemicals. Additionally, the utilization of IPM practices improves the overall management of farm inputs. Some examples of IPM techniques include scouting, planting resistant varieties, crop rotation, and utilizing biological controls.

Current data show that more than 30 percent of the cropland acreage within the watershed is under some level of IPM. These data, however, are inconsistent between the states and may not capture the total number of acres under IPM. The Pesticide Workgroup (workgroup) of the Toxics Subcommittee is currently initiating efforts to capture data on the adoption of IPM techniques within the Chesapeake Bay watershed to determine the level of education and outreach efforts necessary to increase IPM.

To determine the potential impacts to the Bay, a current pesticide usage analysis must be completed to determine what pesticides are actually being used. This will allow IPM managers to focus efforts on those pesticides with the highest risk as well as determine a baseline from which to measure any decrease in pesticide use.

### **PESTICIDE USAGE ANALYSIS**

Pesticide use in the Chesapeake Bay watershed in terms of pounds of active ingredient (AI) applied is targeted mainly toward weed control on agronomic crops. The control of competitive weed populations in corn, soybeans, alfalfa, and small grains through pesticide inputs allows farmers to minimize labor, equipment, and time constraints associated with specific farm economics.

This chapter summarizes usage estimates from 1990 - 1996 for those pesticides that are

used most frequently on the four major crops within the Chesapeake Bay watershed: corn, alfalfa, soybeans, and small grains (wheat, oats/rye, and barley). These crops represent approximately 80-90 percent of all cropland within the watershed, excluding other hay and land used for pasture. The data for the remaining crops that represent 10-20 percent of the cropland will not likely be as reliable at the state level. Thus, these data were not presented. Data gathering techniques utilized for this usage analysis are explained later in this chapter.

Although this analysis quantifies only the most frequently used pesticides on each of the four crops, there are also several others which were listed that show relatively minor usage across all three states. For example, although only 10,000 pounds AI of aldicarb were applied to soybeans in 1996, it was the only insecticide that displayed any quantifiable usage. Thus, it was included in the table to provide the reader with an idea of which insecticide was typically chosen. If these pesticides were not unique in some fashion, they were not included in the table.

Figures 7.3 and 7.4 provide a trend analysis of pesticide usage from 1990-1996 in terms of pounds AI applied to agricultural lands and multiple acres treated within the Bay watershed. These tables provide context to the chemical specific analysis provided in Tables 7.1-7.5. The differences between the aggregated 1996 estimates presented in Table 7.1 and those presented in Figures 7.3 and 7.4 can be explained by the number of chemicals accounted for in each of the analyses. The number of chemicals accounted for in Tables 7.1-7.5 is a subset of the total range of pesticides presented in Figures 7.3 and 7.4.

Additionally, Figures 7.3 and 7.4 show that pesticide usage is variable from year to year due to several factors including weather, pest pressure, product availability, price, and regulatory concerns. Other limitations of these data will be discussed later in this chapter as well as steps necessary to better quantify usage within this region.

Table 7.1 provides aggregated totals and Tables 7.2-7.5 provide a summary of the major pesticides usage for the aforementioned crops. Usage on Tables 7.2-7.5 is shown for each crop, by chemical and state. Pesticides that showed relatively minor usage are listed at the bottom in the "Notes" section. It is important to note that all of these tables present the data as total pounds AI on multiple acres treated. Multiple acre treatments occur when a given pesticide is applied more than once to the same acre in a particular year. This allows us to present the total pounds AI applied annually of a given pesticide.

The herbicides that were used most frequently (atrazine and metolachlor) in the Bay watershed constitute the bulk of overall pesticide usage and are applied at relatively stable rates of application from year to year. Atrazine and metolachlor represent two families of herbicides which account for the majority of groundwater concerns in this country. IPM approaches could potentially reduce these risks.

### *Corn*

Table 7.2 shows that in 1996, about 6.5 million pounds AI were applied to about 5.5 million acre treatments. Atrazine is the largest contributor to this total with about 35 percent of the total pounds AI and multiple acres treated. Atrazine (35 percent), metolachlor (26 percent), pendimethalin (8 percent), and alachlor (7 percent) represent more than 75 percent of the total pounds AI applied. Herbicides account for nearly 95 percent of the total pounds AI applied to corn.

### *Alfalfa*

Based on historical estimates, pesticide usage was relative low for alfalfa in 1996. Previous year estimates show that it would not be uncommon for usage to exceed 1996 estimates fourfold. Table 7.3 shows that approximately 112,000 acre treatments were treated with 70,000 pounds AI in 1996. Dimethoate (33 percent) and chlorpyrifos (14 percent) represent the largest pesticides used in terms of pounds AI. Dimethoate (32 percent), carbofuran (13 percent), and chlorpyrifos (12 percent) represent the largest usage in terms of multiple acre treatments. All of these chemicals are considered insecticides and accounted for two thirds of all pesticides applied to alfalfa.

### *Soybeans*

Pesticide usage was relatively low for soybeans in 1996 compared to other years. However, it was still in the range of other years which was not the case for alfalfa. Table 7.4 shows that approximately 1.4 million pounds AI were applied to more than 1.7 million acre treatments. Metolachlor (42 percent), alachlor (14 percent), and glyphosate (13 percent) accounted for nearly 70 percent of the total pounds AI applied. Aldicarb, which accounted for less than 1 percent of total usage, was the sole insecticide that made the list.

### *Small Grains*

Table 7.5 presents usage on small grains (wheat, oats/rye, and barley) and shows that more than one million acre treatments received a pesticide application in 1996. 2,4-D accounted for 31 percent of the 183,000 pounds AI applied to these sites. In addition to 2,4-D, glyphosate (17 percent) and disulfoton (15 percent) represented more than 60 percent of pesticides applied. Small grains received the lowest typical rates of any of the crops with an average rate of less than 0.2 pounds AI/acre/year for all of the pesticides combined. Small grains were the only crops in which a fungicide (mancozeb, propiconazole, and tridimefon) made the list of major chemicals used.

Corn accounted for 79 percent of the total pounds AI applied to the four crops within the Bay watershed in 1996. Soybeans accounted for 18 percent of total pesticide usage, small grains

accounted for 2 percent, and alfalfa received less than one percent of all pesticides applied. 1,985,000 acres of corn (42 percent), 1,140,000 acres of soybeans (23 percent), 990,000 acres of small grains (20 percent), and 740,000 acres of alfalfa (15 percent) were planted in the Bay watershed in 1996. Atrazine (28 percent) and metolachlor (28 percent) accounted for over half of all pesticides applied to these four sites.

Additionally, Pennsylvania, Maryland and Virginia accounted for 49%, 28%, and 23%, respectively, of the total pounds AI applied and multiple acres treated. Herbicides accounted for approximately 95 percent of the total pounds AI applied to these four crops.

## **DISCUSSION OF DATA GATHERING TECHNIQUES AND LIMITATIONS**

It is vitally important to note that pesticide usage is variable and may or may not represent an average year for any specific site analyzed. Several factors can influence pesticide usage in any given year. Some of these factors include pest pressure, economics, weather, regulatory concerns, etc. Thus, this analysis provides only a snapshot of chemical specific pesticide usage in 1996. The trend analysis attempts to provide a more general overview of pesticide usage.

The pesticide usage estimates are based on proprietary and non-proprietary data sources. Some of the non-proprietary sources include U.S. Department of Agriculture's 1992 National Agricultural Statistics Service, National Agricultural Chemical Association's 1992 Industry Profile, 1992 pesticide usage analysis for the National Center for Food and Agricultural Policy, state surveys, and state pesticide experts. These data were compared to those in the proprietary data sources to derive more reliable estimates.

To establish usage estimates for the watershed, a multiplier was applied to the state usage estimates. This multiplier was derived by dividing the crop specific acreage within the watershed portion of the state by the total acreage of that crop within the entire state. This allowed for the use of state pesticide usage estimates which are more reliable than county estimates because the data is derived from a much larger sample size. Reliable data showing crop acreage within counties that lie within the Bay watershed are available from the states' agricultural statistics service.

Since all data sources have unique limitations, it is preferable to derive pesticide usage estimates from as many sources as possible. Although this analysis did utilize several sources, additional data sets would improve the quality of these data.

Due to agreements with companies that provide proprietary data, point estimates from these sources can not be disclosed. This is another reason several sources are utilized. Proprietary sources provide more validity to those estimates that are publicly available because these sources tend to be more statistically valid. Thus, they are an integral component of this analysis.

## **PESTICIDES IN SURFACE AND GROUND WATER**

As stated earlier in the introduction, the use of pesticides for agricultural and non-agricultural purposes and the potential for these chemicals to adversely affect both surface and ground water as well as the Bay's living resources is a concern of the Chesapeake Bay Program. Many pesticides are soluble in water and may enter the Bay or its tributaries in a dissolved state through storm water and ground water flows.

Ground water delivers more than half of the fresh water that enters the Bay. This water is transported to the Bay as base flow to non-tidal tributaries or upwelled directly to the mainstem and tidal tributaries. Although the Bay is not utilized for drinking water, excessive pesticide exposure could have negative impacts on the overall ecosystem.

Pesticides and/or their metabolites are typically persistent in the environment. This characteristic can result in undesirable loads to surrounding ground and surface water. Estimates of these loads for select pesticides are reported in the fall line and atmospheric deposition chapter of this inventory.

Additionally, this section provides a summary of ambient levels of high use pesticides found in surface and ground water. The United States Geological Survey (USGS) recently released two reports entitled "Pesticides in Surface Water of the Mid-Atlantic Region" and "Nitrate and Selected Pesticides in Ground Water of the Mid-Atlantic Region." Along with the pesticide usage data, these reports provide a comprehensive view of where these chemicals are being detected in ground water and surface water samples.

Table 7.6 and Figure 7.1 summarize data for the high use pesticides detected in surface water. Four pesticides (atrazine, metolachlor, simazine, and 2,4-D) were detected in over 50 percent of the sites sampled. The remaining six pesticides were only detected at 7-30 percent of the sites sampled. Chlorpyrifos concentrations in surface water exceeded the federal acute ambient water quality criterion once (0.14 percent of analyses) and the chronic criterion twice (0.28 percent of analyses). There are no chronic or acute criteria for the other high use pesticides. Atrazine was detected in over 90 percent of the sites sampled and 86 percent of analyses. Concentrations ranged from 0.002-25 ug/l, well below the level judged to be ecologically significant (50 ug/l; Solomon et al., 1996).

Table 7.7 and Figure 7.2 provide a summary of data related to pesticides detected in ground water. The number of detections in ground water was significantly less than what was found in surface water. Atrazine was the only pesticide detected in greater than 50 percent of the sites sampled. It should be noted that both Tables 7.6 and 7.7 present data for only those high use pesticides listed in Table 7.1 and for which USGS screened for.

## **RECOMMENDATIONS**

- ▶ The link between pesticide usage, ambient levels in the Bay and the potential for negative impacts to the ecosystem is unclear. This area should be the primary focus for additional research efforts. Additionally, these efforts should not focus solely on pesticides but include heavy metals and nutrients as well.
- ▶ In order to ensure that ambient concentrations of the high use pesticides in the Chesapeake Bay are below levels that cause adverse impacts on aquatic life, ambient water quality criteria must be developed.

Table 7.1. Pesticide Usage on the Four Major Crops Grown Within the Chesapeake Bay Watershed by Chemical Name, 1996<sup>1</sup>.

Chemical Name	Pounds Active Ingredient (AI) (000)				Multiple Acres Treated <sup>2</sup> (000)				Typical Rate Pounds AI/Acre/Year			
	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	AVERAGE
2,4-D (H)	49	111	43	203	109	186	56	351	0.5	0.6	0.8	0.6
Alachlor (H)	96	261	296	653	48	136	134	318	2.0	1.9	2.2	2.1
Atrazine (H)	610	1,241	419	2,270	447	1,061	305	1,813	1.4	1.2	1.4	1.3
Carbofuran (I)	30	60	24	114	32	64	25	121	0.9	0.9	1.0	0.9
Chlorpyrifos (I)	39	116	50	205	36	112	67	215	1.1	1.0	0.7	1.0
Cyanazine (H)	79	248	15	342	56	144	9	209	1.4	1.7	1.7	1.6
Dicamba (H)	37	56	8	101	186	180	27	393	0.2	0.3	0.3	0.3
Glyphosate (H)	154	170	101	425	196	164	119	479	0.8	1.0	0.8	0.9
Metolachlor (H)	640	1,046	586	2,272	379	643	373	1,395	1.7	1.6	1.6	1.6
Metribuzin (H)	40	17	21	78	150	58	82	290	0.3	0.3	0.3	0.3
Paraquat (H)	110	40	79	229	230	60	153	443	0.5	0.7	0.5	0.5
Pendimethalin (H)	26	542	45	613	36	514	49	599	0.7	1.1	0.9	1.0
Simazine (H)	131	74	39	244	108	54	35	197	1.2	1.4	1.1	1.2
TOTAL <sup>3</sup>	2,041	3,982	1,726	7,749	2,013	3,376	1,434	6,823	N/A	N/A	N/A	N/A

<sup>1</sup> -The acreage of these crops across the three states are as follows: corn - 1,985,000, soybeans - 140,000, small grains - 990,000, and alfalfa - 740,000.

<sup>2</sup> - Includes multiple applications of a given pesticide on the same acre in the same year.

<sup>3</sup> - Totals may not add down or across due to rounding.

Notes:

- H = Herbicide, I = Insecticide, N/A = Not Applicable, - = Unknown
- Please see Tables 1 - 4 for those pesticides which showed relatively insignificant usage across all three states.
- Data based on several proprietary and non-proprietary sources.

Table 7.2. Pesticide Usage on Corn in the Chesapeake Bay Watershed by Chemical Name, 1996<sup>1</sup>.

Chemical Name	Pounds Active Ingredient (AI) (000)				Multiple Acres Treated <sup>2</sup> (000)				Typical Rate Pounds AI/Acre/Year			
	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	AVERAGE
2,4-D (H)	37	72	38	147	93	128	46	267	0.4	0.6	0.8	0.6
Alachlor (H)	56	240	152	448	28	128	68	224	2.0	1.9	2.2	2.0
Atrazine (H)	605	1,240	418	2,263	442	1,060	304	1,806	1.4	1.2	1.4	1.3
Carbofuran (I)	28	56	23	107	28	56	23	107	1.0	1.0	1.0	1.0
Chlorpyrifos (I)	37	112	46	195	33	108	61	201	1.1	1.0	0.8	1.0
Cyanazine (H)	79	248	15	342	56	144	9	209	1.4	1.7	1.7	1.6
Dicamba (H)	37	56	8	101	186	180	27	393	0.2	0.3	0.3	0.3
Glyphosate (H)	60	128	15	204	79	112	19	210	0.8	1.1	0.8	1.0
Metolachlor (H)	465	880	319	1,664	279	560	209	1,048	1.7	1.6	1.5	1.6
Paraquat (H)	79	32	49	160	163	44	91	298	0.5	0.7	0.5	0.5
Pendimethalin (H)	<1	500	4	505	<1	460	4	465	-	1.1	1.0	1.1
Simazine (H)	130	72	38	240	107	52	34	193	1.2	1.4	1.1	1.2
Terbufos (I)	56	40	15	111	37	32	11	81	1.5	1.3	1.3	1.4
TOTAL <sup>3</sup>	1,670	3,676	1,140	6,486	1,531	3,064	906	5,501	N/A	N/A	N/A	N/A

<sup>1</sup> - 1,985,000 acres of corn were grown in the watershed in 1996 (MD - 495,000; PA - 1,150,000; VA - 340,000)

<sup>2</sup> - Includes multiple applications of a given pesticide on the same acre in the same year.

<sup>3</sup> - Totals may not add down or across due to rounding.

Notes:

- H = Herbicide, I = Insecticide, N/A = Not Applicable, - = Unknown
- Acetochlor, bromoxynil, butylate, dimethenamid, EPTC, esfenvalerate, icosulfuron, methyl parathion, permethrin, phorate, primisulfuron, and tefluthrin all showed relatively insignificant usage across all three states.
- Data based on several proprietary and non-proprietary sources.



Table 7.3. Pesticide Usage on Alfalfa in the Chesapeake Bay Watershed by Chemical Name, 1996<sup>1</sup>.

Chemical Name	Pounds Active Ingredient (AI) (000)				Multiple Acres Treated <sup>2</sup> (000)				Typical Rate Pounds AI/Acre/Year			
	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	AVERAGE
2,4-DB (H)	<1	4	1	6	<1	8	1	10	-	0.5	0.5	0.5
Carbofuran (I)	2	4	1	7	4	8	2	14	0.5	0.5	0.5	0.5
Chlorpyrifos (I)	2	4	4	10	3	4	6	13	0.7	1.0	0.8	0.8
Dimethoate (I)	2	20	1	23	4	28	4	36	0.5	0.7	0.3	0.7
EPTC (H)	<1	2	1	4	<1	<1	1	3	-	1.6	2.0	1.5
Hexazinone (H)	2	2	<1	5	2	2	<1	5	1.0	1.0	-	1.0
Paraquat (H)	1	4	1	6	2	8	1	11	0.5	0.5	0.5	0.5
Permethrin (I)	<1	4	<1	6	4	12	<1	17	0.3	0.3	-	0.4
Simazine (H)	1	2	1	3	1	2	1	3	1.0	1.0	1.0	1.0
TOTAL <sup>3</sup>	13	45	12	70	22	72	18	112	N/A	N/A	N/A	N/A

<sup>1</sup> - 740,000 acres of alfalfa were grown in the watershed in 1996 (MD - 60,000; PA - 600,000; VA - 80,000)

<sup>2</sup> - Includes multiple applications of a given pesticide on the same acre in the same year.

<sup>3</sup> - Totals may not add down or across due to rounding.

Notes:

- H = Herbicide, I = Insecticide, N/A = Not Applicable, - = Unknown
- 1996 was a relatively low year for pesticide usage on alfalfa.
- 2,4-D, methyl parathion, metribuzin, pendimethalin, phosmet, sethoxydim, and terbacil all showed relatively insignificant usage across all three states.
- Data based on several proprietary and non-proprietary sources.

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Table 7.4. Pesticide Usage on Soybeans in the Chesapeake Bay Watershed by Chemical Name, 1996<sup>1</sup>.

Chemical Name	Pounds Active Ingredient (AI) (000)				Multiple Acres Treated/2 (000)				Typical Rate Pounds AI/Acre/Year			
	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	AVERAGE
Acifluorfen (H)	5	2	12	19	10	4	37	51	0.5	0.4	0.3	0.4
Alachlor (H)	40	21	144	204	20	8	66	94	2.0	2.5	2.2	2.2
Aldicarb (I)	<1	<1	8	10	<1	<1	8	10	-	-	1.0	1.0
Dimethanamid (H)	65	<1	<1	67	55	<1	<1	57	1.2	-	-	1.2
Fomesafen (H)	<1	<1	16	18	<1	<1	45	47	-	-	0.4	0.4
Glyphosate (H)	80	37	74	191	105	46	90	241	0.8	0.8	0.8	0.8
Imazaquin (H)	5	2	7	13	30	8	16	55	0.2	0.2	0.4	0.2
Imazethapyr (H)	5	4	4	13	50	50	61	161	0.1	0.1	0.1	0.1
Linuron (H)	15	14	21	50	30	29	45	104	0.5	0.5	0.5	0.5
Metolachlor (H)	175	166	267	608	100	83	164	347	1.8	2.0	1.6	1.8
Metribuzin (H)	40	17	21	77	150	58	82	290	0.3	0.3	0.3	0.3
Paraquat (H)	30	4	29	63	65	8	61	135	0.5	0.5	0.5	0.5
Pendimethalin (H)	25	42	41	108	35	54	45	134	0.7	0.8	0.9	0.8
TOTAL <sup>3</sup>	487	311	643	1,441	652	352	723	1,726	N/A	N/A	N/A	N/A

<sup>1</sup> - 1,140,000 acres of soybeans were grown in the watershed in 1996 (MD - 490,000; PA - 240,000; VA - 410,000).

<sup>2</sup> - Includes multiple applications of a given pesticide on the same acre in the same year.

<sup>3</sup> - Totals may not add down or across due to rounding.

Notes:

- H = Herbicide, I = Insecticide, N/A = Not Applicable, - = Unknown
- 2,4-D, 2,4-DB, bentazone, chlorimuron, clethodim, clomazone, fenoxaprop, fluazifop, flumetsulam, sethoxydim, permethin, and trifluralin all showed relatively insignificant usage across all three states.
- Data based on several proprietary and non-proprietary sources.

Table 7.5. Pesticide Usage on Small Grains in the Chesapeake Bay Watershed by Chemical Name, 1996<sup>1</sup>.

Chemical Name	Pounds Active Ingredient (AI) (000)				Multiple Acres Treated <sup>2</sup> (000)				Typical Rate Pounds AI/Acre/Year			
	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	TOTAL <sup>3</sup>	MD	PA	VA	AVERAGE
2,4-D (H)	12	39	5	56	16	58	10	84	0.8	0.7	0.5	0.7
Atrazine (H)	5	<1	<1	7	5	<1	<1	7	1.0	-	-	1.0
Disulfoton (I)	<1	<1	25	27	<1	<1	33	35	-	-	0.8	0.8
Glyphosate (H)	14	5	12	31	12	6	10	28	1.2	0.8	1.3	1.1
Lambda-cyhalothrin	1	<1	2	4	74	<1	62	138	0.0	-	0.0	0.0
MCPA (H)	2	12	<1	14	7	31	<1	38	0.3	0.4	-	0.4
Mancozeb (F)	<1	7	<1	9	<1	5	<1	7	-	1.5	-	1.3
Propiconazole (F)	9	2	4	15	74	15	33	123	0.1	0.1	0.1	0.1
Thifensulfuron (H)	5	2	2	8	140	27	108	274	0.0	0.1	0.0	0.0
Triadimefon (F)	5	1	<1	6	28	5	<1	34	0.2	0.1	-	0.2
Tribenuron (H)	5	2	1	7	140	27	100	266	0.0	0.1	0.0	0.0
TOTAL <sup>3</sup>	59	70	55	183	497	177	360	1,034	N/A	N/A	N/A	N/A

<sup>1</sup> - 990,000 acres of small grains were grown in the watershed in 1996 (MD - 300,000; PA - 380,000; VA - 310,000)

<sup>2</sup> - Includes multiple applications of a given pesticide on the same acre in the same year.

<sup>3</sup> - Totals may not add down or across due to rounding.

Notes:

- F = Fungicide, H = Herbicide, I = Insecticide, N/A = Not Applicable, - = Unknown.
- 2,4-DB, aldicarb, bromoxynil, carbaryl, carbofuran, dicamba, diclofop, dimethoate, paraquat, malathion, methomyl, and thiodicarb all showed relatively insignificant usage across all three states.
- Data based on several proprietary and non-proprietary source.

Table 7.6. High Use Pesticides in Surface Water Sampled in the Chesapeake Bay Watershed (1993-1996).

Pesticide	Number of Analyses *	Number of Detections	Percent of Analyses with Detections	Number of Sites Sampled	Number of Sites with Detections	Percent of Sites with Detections	Acute Criterion (ug/l)	Number of Acute Exceedences	Chronic Criterion (ug/l)	Number of Chronic Exceedences
2,4-D	264	39	14.8	17	9	52.9				
ALACHLOR	1012	398	39.3	279	73	26.2				
ATRAZINE	1013	875	86.4	279	252	90.3				
CARBOFURAN	713	47	6.6	272	24	8.8				
CHLORPYRIFOS	732	113	15.4	271	27	10.0	0.0830	1	0.0410	2
CYANAZINE	781	252	32.3	279	83	29.7				
METOLACHLOR	1012	832	82.2	279	231	82.8				
METRIBUZIN	732	62	8.5	271	21	7.7				
PENDIMETHALIN	709	112	15.8	271	19	7.0				
SMAZINE	1012	821	81.1	279	228	81.7				

\* The number of analyses refers to the number of samples for a pesticide that are unique for a station, date, time, and medium.

Note: These data are from USGS's Mid-Atlantic Assessment (MAIA) project: pesticide concentrations from 463 surface water sites. Only data from 1993-1996 within the Chesapeake Bay Watershed were used for this analysis. These data are referenced in the USGS Water-Resources Investigations Report 97-4280 entitled "Pesticides in Surface Water of the Mid-Atlantic Region."

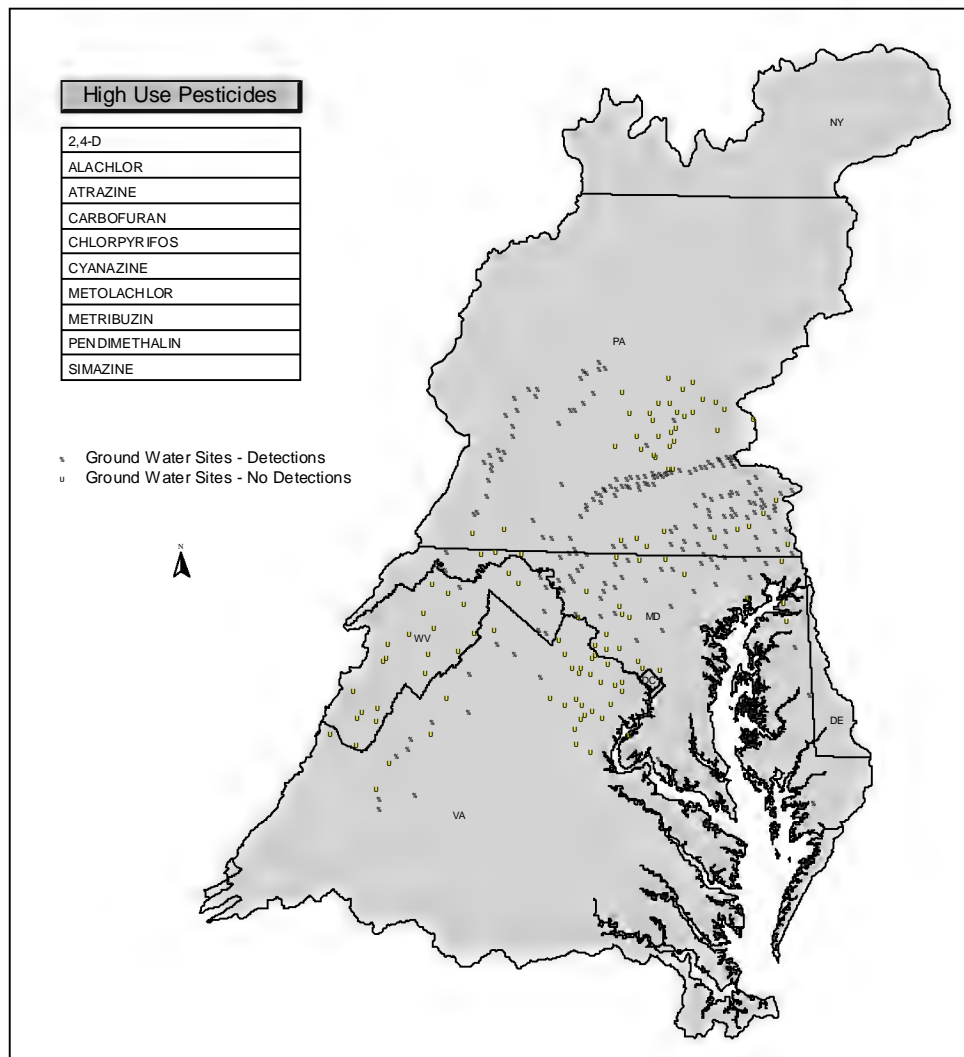
Table 7.7. High Use Pesticides in Ground Water Sampled in the Chesapeake Bay Watershed (1993-1996).

<b>Pesticide</b>	<b>Number of Analyses</b>	<b>Number of Detections</b>	<b>Percent of Analyses with Detections</b>	<b>Number of Sites Sampled</b>	<b>Number of Sites with Detections</b>	<b>Percent of Sites with Detections</b>
2,4-D	261	1	0.4	259	1	0.4
ALACHLOR	322	20	6.2	309	20	6.5
ATRAZINE	323	184	57.0	310	178	57.4
CARBOFURAN	315	7	2.2	304	6	2.0
CHLORPYRIFOS	314	0	0.0	303	0	0.0
CYANAZINE	314	12	3.8	303	12	4.0
METOLACHLOR	323	140	43.3	310	134	43.2
METRIBUZIN	322	3	0.9	309	3	1.0
PENDIMETHALIN	314	1	0.3	303	1	0.3
SIMAZINE	323	119	36.8	310	115	37.1

\* The number of analyses refers to the number of samples for a pesticide that are unique for a station, date, time, and medium.

Note: These data are from USGS's Mid-Atlantic Assessment (MAIA) project: nitrogen and pesticide concentrations for 937 ground water sites. Only data from 1993-1996 within the Chesapeake Bay Watershed were used for this analysis.

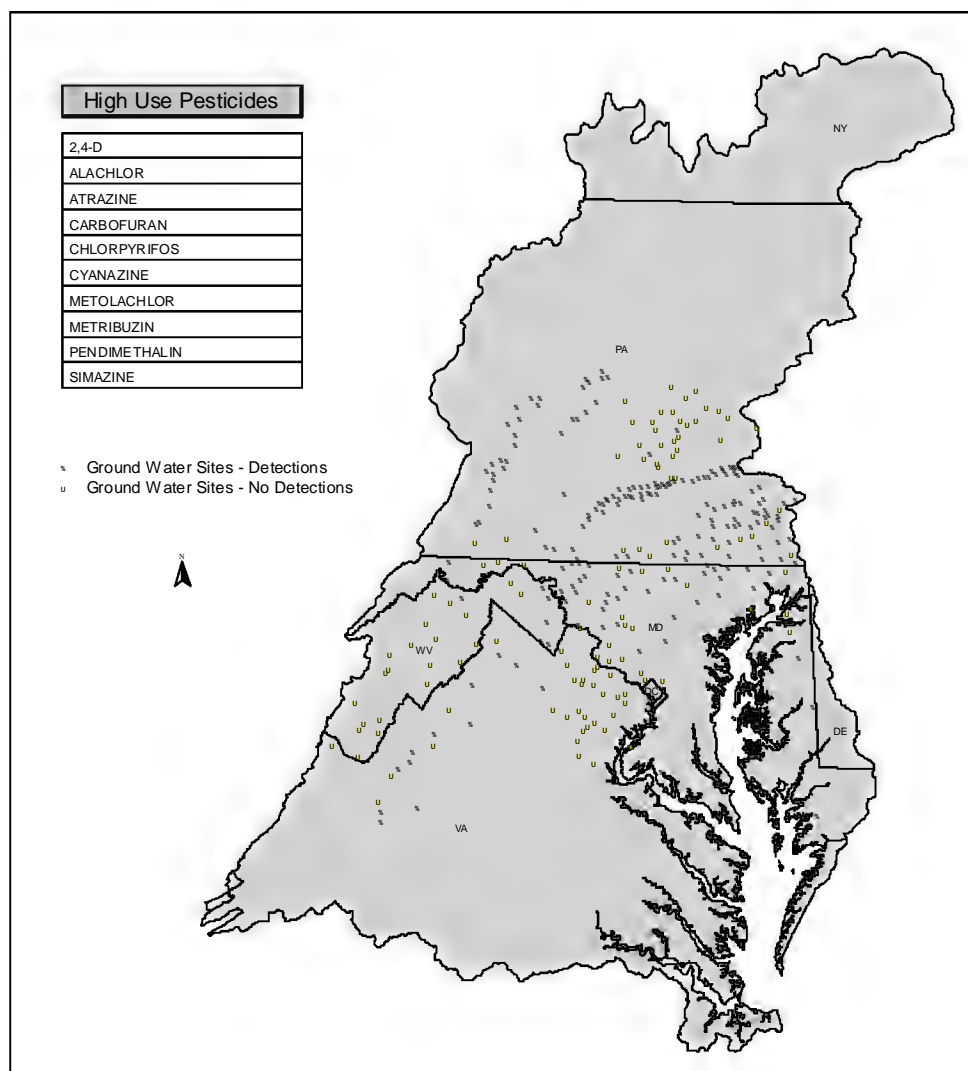
### High Use Pesticides in Ground Water Sampled in the Chesapeake Bay Watershed (1993-1996)



Note: These data are from USGS's Mid-Atlantic Assessment (MAIA) project: nitrogen and pesticide concentrations for 937 ground water sites. Only data from 1993-1996 within the Chesapeake Bay Watershed were used for this analysis.

Figure 7.1. Surface water pesticide detection sites.

# High Use Pesticides in Ground Water Sampled in the Chesapeake Bay Watershed (1993-1996)



Note: These data are from USGS's Mid-Atlantic Assessment (MAIA) project: nitrogen and pesticide concentrations for 937 ground water sites. Only data from 1993-1996 within the Chesapeake Bay Watershed were used for this analysis.

Figure 7.2. Ground water pesticide detection sites.

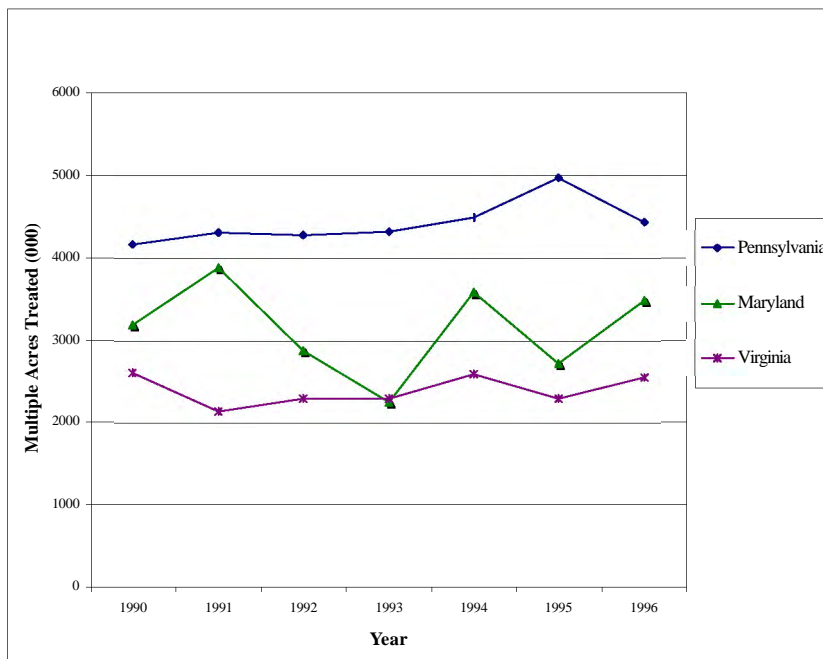


Figure 7.3. Multiple Acres Treated With Pesticides Within the Watershed.

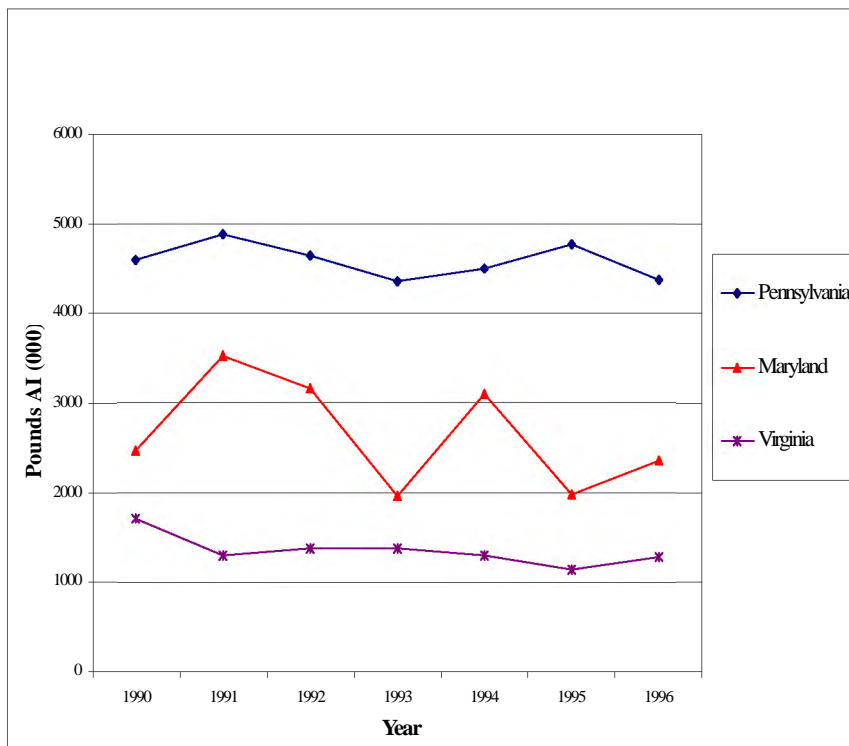


Figure 7.4. Pounds of Pesticide Active Ingredients Applied to Agricultural Lands Within the Watershed.



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## CHAPTER 8 - Relative Importance of Point and Non-Point Sources of Chemical Contaminants to Chesapeake Bay

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### INTRODUCTION

This chapter compares the loadings of selected contaminants from point and nonpoint sources to assess the relative importance of each source in contributing loads to the tidal Bay and its major tidal rivers. This comparison of loadings from each source category will enable managers to determine where to focus limited resources for source reductions in specific areas of the Chesapeake Bay watershed. Specific objectives of this chapter are to: 1) combine loading estimates from individual sources (as described in the previous chapters) to yield annual loadings of selected contaminants to the mainstem Chesapeake Bay and tributaries; 2) compare the magnitudes of individual loadings to assess the relative importance of each source type; 3) examine the errors and uncertainties in the current estimated loadings; and 4) recommend further actions to reduce the uncertainty in loadings to the Bay. Sources such as atmospheric deposition, urban runoff, point sources, and fall line inputs to the tidal Bay are examined and augmented with shoreline erosion rates, where possible. Loads for selected contaminants are presented for the mainstem tidal area as well as major sub-tributaries of Chesapeake Bay such as the Potomac, James, and Patuxent rivers. In addition, estimates are made for the Anacostia watershed which was designated by the Chesapeake Executive Council as one of three *Regions of Concern*. The Anacostia had the most complete data set of the three areas.

### METHODOLOGY

Specific chemicals that were investigated for this comparative analysis include selected trace elements arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), and zinc (Zn). Loading information was also compiled for organic contaminants including total polychlorinated biphenyls (PCBs) and specific polycyclic aromatic hydrocarbons (PAHs) such as chrysene, phenanthrene, pyrene, and benzo(a)pyrene. These chemicals were chosen due to their inclusion in the Chesapeake Bay Toxics of Concern List (CBP, 1998) and availability of data for the various sources.

The data for this analysis and the limitations of each data set are presented in previous chapters of this report. In general, the sources chosen for these estimates include point sources

## *Comparative Loadings in the Bay*

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(municipal, industrial, and federal), non-point sources (shoreline erosion and urban runoff), riverine runoff from upstream sources (loads from the non-tidal portion of the watershed entering tidal waters at the fall line), and atmospheric deposition (Figure 8.1). For this comparative loadings analysis, loadings to the tidal portion of the Chesapeake Bay rivers are fall line loadings, representing the total loadings from upstream sources, and below fall line loadings from point sources, atmospheric deposition, urban runoff and shoreline erosion. The fall line is the zone between tidal and non-tidal waters of each tributary. For this report, fall line inputs are the integrated sum of the various sources within the watershed. They include point source and non-point sources upstream of the fall line. Below are brief descriptions of the methods used for each source category for this chapter.

### *Point Source*

Loadings from the Point Source chapter (Chapter 1) for the chemicals indicated above were used for this analysis, and unless otherwise noted, the high and low estimates were averaged. For the trace metals, dissolved, total recoverable, or total loads are reported in Chapter 1. This was due to the reporting method and type of chemical analysis by each facility. In this chapter, the highest load from these three categories was used for comparison. Lastly, loads for total PCBs were estimated from Arochlor 1260 only. All loads are reported in pounds per year (lb/yr).

### *Urban Stormwater Runoff*

Data were obtained from Chapter 2 of this document. In brief, runoff volumes were calculated from relationships between rainfall, land use, and impervious area. Chemical loads were determined from the runoff volume and literature-derived event-mean concentrations of specific chemical contaminants. All loads are reported in pounds per year (lb/yr).

### *Shoreline Erosion*

To provide a rough estimate of loads of chemical eroding from shoreline sediments, data presented in Helz et al. (1985) and Bryne and Anderson (1973) were used. From these studies, the average mass erosion rates (kg sediment/yr) were obtained directly or calculated from volume erosion rates ( $\text{m}^3$  sediment /yr) and estimates of bulk sediment density. Metal fluxes were calculated using the average concentrations for shoreline material derived from Helz et al. (1985) and are reported as lb/yr. Errors inherent in these calculations include the use of average rates and concentrations throughout the Bay given the geochemical variability of shoreline material. In addition, shoreline material is generally more coarse and would only be transported during storm events. However, these estimates do provide an order of magnitude estimate from shoreline sources. All loads are reported in pounds per year (lb/yr).

### *Atmospheric Deposition*

Atmospheric deposition samples were collected from three stations located around the edge of the Bay starting in late 1990 or early 1991 to 1993 from the Chesapeake Bay Atmospheric Deposition Program. Wet deposition samples were collected weekly or bi-weekly, while dry deposition was estimated from measured aerosol concentrations and particle deposition rates (See Chapter 3 for details). Estimates are to the tidal waters of the Bay and tributaries only.

The loading rates in Chapter 3 were modified to include an urban source effect using data from Baltimore Harbor and the amount of urban area in the Bay region. Additionally, loads are direct to the surface waters (i.e., gross absorptive fluxes) and are not corrected for gas or aerosol exchange back into the overlying air mass unless noted. This is especially important for organic contaminants such as PCBs and aromatic hydrocarbons, and for mercury for which gas exchange from the water to the atmosphere can be substantial. All loads are reported in pounds per year (lb/yr).

### *Fall Line (i.e., Upstream Sources)*

Fall line inputs are those directly delivered to the tidal waters of the specific tributary and Bay. The fall line, for this report, is the boundary between tidal and non-tidal waters. Fall line estimates provide a measure of the amount of material discharged or released from all sources in a watershed above the fall line and delivered to the upper reaches of the Bay's tidal tributaries (i.e., James River) or the upper mainstem Bay (i.e., Susquehanna River). Estimates are derived from the data presented in Chapter 6 for the mainstem Bay and various tributaries and from Gruessner et al. (1997) for the Anacostia River. All loads are reported in pounds per year (lb/yr).

Chemicals in fall line transport are derived from many upstream sources, both natural and anthropogenic. As such, above fall line (AFL) inputs include point sources, urban runoff, stream bank erosion, agricultural sources, acid mine drainage, and atmospheric deposition, among others. It is not possible at this time to subdivide the total fall line loads by specific contributing sources. While most sources discharge or are calculated to discharge to the free-flowing river, atmospheric inputs are deposited to all surface areas (land and water) within the watershed and need to be transported to the river. There are many attenuating processes that can sequester a portion of the atmospherically-derived metals or organic compounds before they reach the adjacent creek, stream or river, and many of these processes are chemical specific due to different geochemical reactions. Also, once a chemical is introduced into the free-flowing river, similar geochemical processes can act on the contaminant and can alter the amount of material eventually transported over the fall line into tidal waters. Therefore, it is difficult to allocate the above fall line sources noted in the previous chapters into what is actually measured at the fall line.

## *Comparative Loadings in the Bay*

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### *Other Sources*

This updated inventory, although more complete than the 1994 inventory, is not a comprehensive accounting of all loads of all chemical contaminants to the Bay and its tidal rivers. The load for only a subset of all chemical contaminants entering the Bay were measured or estimated, and some sources of chemical contaminants loads are not quantified or separated from the total load. For example, the load to the Bay that is measured at the fall line is the sum of all sources in the non-tidal watershed including atmospheric deposition to the watershed, natural weathering of rock and soils, agricultural sources from chemical applications, point sources, and stormwater runoff. However, due to the lack of adequate data, it is not possible to allocate the total load into its components. Other sources of loads that have not been fully accounted for or separated from the various loads are the following:

- Point source loads from over 3,700 minor facilities that discharge with a flow of less than 0.5 million gallons per day,
- The fraction of the atmospheric deposition load that is carried off the watershed (i.e., the land) into the Bay by stream or river runoff,
- The fraction of the agricultural load that is carried off agricultural land by atmospheric deposition and subsequent stream runoff,
- Groundwater loads both direct to the tidal Bay and the fraction of the fall line load to the tidal waters and,
- Natural background loads of chemicals (i.e., trace metals) entering the Bay from natural process such as mechanical or chemical weathering of rock.

Some of these loads are captured through fall line load estimates and possibly urban runoff estimates, while others (e.g., direct agricultural loads) were not estimated due to a lack of accurate data. Therefore, in the figures in this chapter, another category has been added called “other sources” to remind the reader that this is not a comprehensive inventory and there are some sources that are not completely accounted for or separated from other source categories.

### *Uncertainty Analysis of Loads*

The determination and quantification of the important input fluxes to Chesapeake Bay are complex tasks. Many problems are inherent in these types of calculations including: 1) a general lack of quality data; 2) incomparability of chemical measurements and forms from each source category; and 3) incomplete reporting of the various sources as discussed in the previous loading chapters. There is some level of uncertainty in all loads estimates that are due to a number of factors (i.e., both systematic and random) ranging from uncertainty in measurements, spatial extrapolation, temporal variation in rainfall or streamflow, and the method used to estimate loads. While it would be best to have a consistent method to estimate the uncertainty in each source category, this may not be possible given the available data. In many cases the level of uncertainty can be fairly accurately calculated while in some cases the level of uncertainty can

only be estimated. The major cause of error and temporal variation was provided in each chapter and was incorporated into the comparative loadings analysis. Below is a summary of the uncertainty analysis that was provided within each source category:

#### Atmospheric loads

Baker (Chapter 3) estimated that sources of random error in wet deposition loading estimates include the measurement errors associated with quantifying chemical concentrations in precipitation and the rainfall amount. For atmospheric wet deposition, the propagated uncertainties to the metals and organics fluxes were estimated at  $\pm 10\%$  and  $\pm 20\%$ , respectively. It was estimated that dry aerosol deposition loadings are likely precise to within a factor of 2-3. In addition, the overall random error of a typical instantaneous gas exchange flux was calculated as  $\pm 40\%$ . Lastly, a potentially larger source of uncertainty in deposition loadings results from the spatial extrapolation from the few regional and single urban deposition sites to the Bay.

#### Point Source loads

A formal uncertainty analysis for point source loads has not been calculated due to the nature of the data set (Chapter 1). While there are random errors in the calculation of the load, systematic errors in reporting may also be large. Current methods for estimating organic loads from point sources are highly uncertain and of limited use, particularly for the organic contaminants. Reporting programs in which data were collected were not set up with the objective of calculating loads, but rather for determining compliance with regulated parameters in discharge permits. For certain chemicals -- all PCBs, pesticides, and most PAHs -- most or all values were reported at below the detection limits. In addition the detection limit used or provided may be unduly high relative to the regulatory-based method used for analysis. Therefore loading estimates for these contaminants may be as low as zero or as high as the detection limit multiplied by the flow. However, this uncertainty is not the case for most of the trace metal data since many measurements were above the detection limit. The range of estimates based upon the detection limit and flow were used to estimate the likely bounds for the loads and can be very large dependent on the number of samples that are below the detection limit.

As eluded to above, one of the largest uncertainties in this inventory is the point source load estimate for organic contaminants. In most cases no organic contaminants were detected and the detection limit was high. For measurements of organic contaminants and some trace metals that are below the detection limit, using typical pollutant concentrations (TPC) from the literature (instead of the detection limit) may be a better approach for estimating loads from point sources. Below is an illustration of the use of a typical pollutant concentration (TPC) to help constrain the load estimates, using PCBs as an example. For this example, a TPC is used as a default for point sources that do not have accurate measurements and where detection limits are high. TPCs are simply "typical" concentrations of a chemical for similar industrial activities or processes. The TPC provides a planning level estimate that helps understand the possible relative importance of point sources, and this illustration will help to interpret the point source

organics data presented in this chapter.

Total average PCB loads (i.e., Arochlor 1260) were estimated for the tidal Potomac River to illustrate the uncertainty of the point source estimates. Atmospheric deposition loads are the sums of wet and dry deposition, while removal from the surface water via volatilization was not considered. Fall line loads from the non-tidal watershed were measured over multiple years as part of the Chesapeake Bay Program Fall Line monitoring program (see Chapter 6). As can be seen from Figure 8.2, point source load estimates for PCBs are highly uncertain relative to the other sources. In this regard, virtually all measurements of PCBs are below the detection limit. Therefore concentrations could range between zero and the detection limit (e.g., high  $\mu\text{g/L}$ ), resulting in loads ranging from 0-210,000 lb/yr.

To get an idea of what the actual PCB loads are within this large range, one method would be to assume a typical concentration for total PCBs in point source effluent (based on values in the literature) for those facilities where PCBs would be expected to be present. Loads would be calculated by multiplying the concentration by the point source flows in the tidal portion of the watershed. Recent studies by Durell and Lizotte (1998) and DRBC (1998) showed wastewater treatment plants (WWTP) effluent concentrations of total PCBs much lower compared to the detection limits used for Chesapeake Bay point sources. In 26 WWTP effluents in the NY/NJ Harbor Estuary (Durell and Lizotte, 1998), total PCBs ranged from 0.010 to 0.055  $\mu\text{g/L}$  (sum of 71 target congeners) with an overall average of 0.025  $\mu\text{g/L}$ . Concentrations of total PCBs from 7 WWTP in the tidal freshwater Delaware River (DRBC, 1998), ranged from approximately 0.0014 to 0.045  $\mu\text{g/L}$  with an overall average of 0.013  $\mu\text{g/L}$ .

Assuming a low and high concentration of 0.0014  $\mu\text{g/L}$  and 0.05  $\mu\text{g/L}$ , respectively, approximately 170 lb/yr of PCBs, on average, are entering the tidal Potomac waters from point sources (Figure 8.3). This estimate is three orders of magnitude lower than the estimate made using the given detection limit to calculate loads (200,000 lb/yr). Using literature derived typical pollutant concentrations, the estimated point source loads of PCBs to the tidal Potomac indicate that approximately 60% of the total load is derived from point sources and the fall line loads are comparable to the point source loads, with a very small load originating from atmospheric deposition. Overall, the use of a TPC for point sources in which most or all of the measured concentrations are at the detection limit and the limit appears to be unduly high, may be warranted so that planning level estimates can be derived.

#### Fall line loading estimates

Uncertainties have not been rigorously evaluated for fall line loading estimates (see Chapter 6). The level of uncertainty is related to the variability in the measured concentration and discharge. In addition, estimates of contaminant loadings above the river fall lines are extremely dependent on river flows, which vary widely throughout the year. While loads for the Susquehanna, Potomac and James rivers were averaged over multiple years, loads for many tributaries were obtained for only a single year from only two sampling events. Estimates of

contaminant loadings are dependent on river flow, which can vary substantially from year to year. Also, due to the extreme cost and time for fall line monitoring and chemical analysis, the contaminant concentration data used to estimate loads were sparse. The most accurate loadings exist for the Susquehanna River for which multiple years of data have been collected. For this analysis, four years of loadings data from the Potomac, James and Susquehanna Rivers were used to estimate the overall level of uncertainty. The trace metals, copper, cadmium, and lead, were used as it appears that they had the most complete data set. On average the relative standard deviation was approximately  $\pm 20\%$ , and this value was applied to all fall line loadings.

#### Shoreline erosion loads

Variations in the shoreline erosion estimate was based on the range of estimates between the 1994 estimate from the 1994 Reevaluation Report (CBP, 1994b) and the estimate from the 1982 Technical Synthesis Report (CBP, 1982). These were independently determined and provide some idea as to the range of loads from shoreline sediments.

#### Urban runoff loads

The uncertainty in the urban runoff load estimates were not rigorously determined, but a rough estimate of the quantifiable uncertainty was presented (see Chapter 2). Three main sources of quantifiable error have been identified: modeling error in the average annual runoff estimates, interannual variability in the estimates (i.e., runoff), and variability in the measured chemical contaminant concentrations. A comparison of the basinwide urban land use data that was used in the Chesapeake Bay Watershed Model suggested an estimate of about  $\pm 10\%$  error in the amount of urban land and the percentage of impervious surface associated with those urban areas (Mandel et al., 1997), both of which affect the average annual runoff estimates. There was some additional uncertainty or variation associated with the average annual runoff estimates due to interannual variability in rainfall amounts. To develop an estimate of this uncertainty, 95% confidence intervals were calculated around the mean annual runoff estimates from 1986-1993. The magnitudes of the confidence intervals in either direction, expressed as the percent of the mean, ranged from 9 to 26% and the average was 16%. Combining the  $\pm 10\%$  estimate of modeling error due to land use with the  $\pm 16\%$  error from the interannual runoff variability, the uncertainty in the calculated runoff values is likely to be about  $\pm 25\%$ . A similar approach was taken to determine order of magnitude estimates in the uncertainty of the EMC values. Gruessner et al. estimated a conservative error of  $\pm 54\%$  as an estimate of the uncertainty in the EMC values and since the load estimates are calculated from the product of the runoff and EMC values, the combined quantifiable uncertainties suggest that the average annual loads are approximately  $\pm 60\%$ . This level of uncertainty was applied to all urban runoff estimates.

### **INPUTS TO THE TIDAL CHESAPEAKE BAY**

The loads of selected chemical contaminants to the tidal Chesapeake Bay were calculated by taking the sum of all estimates of loadings entering the tidal rivers of the Bay for atmospheric

### Comparative Loadings in the Bay

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deposition, fall line loads, urban runoff, shoreline erosion, and point sources that are described in previous chapters of this inventory.

#### *Trace Elements*

***Summary: The highest estimated metals load comes from upstream sources (fall line) to the tidal waters of the Bay.***

***Point source loads are important for copper and mercury.***

***Loads from shoreline erosion and urban runoff account for up to 13% of the total metals loads to the tidal Bay.***

In Figures 8.4-8.9, the various inputs of cadmium, copper, lead, mercury, zinc, and arsenic are summarized along with the total load (in lb/yr) to the tidal waters of Chesapeake Bay. The trace metals copper and zinc had the greatest average total load to the tidal Bay of 710,000 lb/yr and 3,300,000 lb/yr, respectively, while mercury had the least, 9,500 lb/yr.

#### Fall Line

All metal loads are dominated by upstream inputs (fall line loads). These loads are likely underestimated because not all Bay tributaries were sampled and quantified; however, this would be a small load since the total flow is dominated by the tributaries that were monitored.

#### Point Sources

Point source inputs are important for mercury and copper. The level of uncertainty in the copper loads estimates is very low because the majority of measurements were above the detection limit. However, there was more uncertainty in the mercury loads estimates because many of the values were below detection limit (see previous discussion of uncertainty for point sources)

#### Shoreline Erosion

Erosion of shoreline material accounts for less than approximately 13% of the total load, with the greatest loads to the tidal Bay for zinc and lead.

#### Urban Runoff

Urban runoff accounts for between 6 and 13% of the total load for these trace elements, the greatest being for lead and zinc.

#### Atmospheric Deposition

Atmospheric inputs of metals directly to tidal waters are a small percentage of the total load and range from approximately 3% for copper and cadmium to 7% for lead. Atmospheric



inputs of lead are approximately twice as high as point source inputs. The importance of this is not just that the load is higher but also that it is spread out over the entire tidal water area, while point source inputs are usually in small bays or tributaries.

#### *Organic Contaminants*

***Summary: Urban stormwater runoff is a substantial source of PAHs to the tidal Chesapeake Bay.***

***Point sources of organic contaminants (PAHs, and PCBs) are highly uncertain and therefore loads are largely unknown.***

***Total PCBs loads are approximately equally divided between atmospheric and fall line loads to the tidal waters of the Bay.***

Estimates for organic contaminant loads to the mainstem tidal Bay are presented in Figures 8.10-8.13 for four polycyclic aromatic hydrocarbons (PAHs, benzo[a]pyrene, chrysene, phenanthrene, and pyrene) and total PCBs (no figure provided). No data for PAH loads from shoreline erosion were available.

For specific aromatic hydrocarbons, average loads range from 130,000 lb/yr for phenanthrene to 64,000 lb/yr for benzo[a]pyrene and chrysene (Figures 8.10-8.13). Total PCB loads to the tidal waters of the Bay, without point source estimates are nearly equally divided between fall line inputs (650 lb/yr) and atmospheric deposition (wet and dry) to the tidal waters (540 lb/yr).

#### Point Sources

Point source loads estimates of PAHs are highly uncertain as indicated by the large uncertainty bars in Figures 8.10-8.13. Virtually all of the measurements of PAHs were below the detection limit. Therefore the loads could range anywhere between zero to the product of the detection limit and flow. Therefore, the point source loads of PAHs are unknown and the data presented in the figures are of limited use.

#### Urban Runoff

Given that point source loads estimates are highly uncertain, the urban stormwater runoff is the most substantial known source of PAH loads to the tidal Bay. Urban runoff accounts for approximately 12% of the total input of PAHs to the tidal Bay. Since the point source loads estimates are so uncertain, the relative contribution of urban runoff is probably much greater than initially estimated. Urban stormwater runoff would include power plant combustion, automobile emissions, both gas/oil combustion and oil drippings, and tire wear.

## *Comparative Loadings in the Bay*

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### Fall Line/Atmospheric Deposition

Inputs from the non-tidal watershed (as measured at the fall line) account for less than 3% of the total load while total atmospheric deposition (i.e., wet, dry, and gas exchange into the water) ranges from < 0.5% for benzo[a]pyrene (77 lb/yr) to 5% for phenanthrene (6,400 lb/yr).

## **INPUTS TO TRIBUTARIES OF CHESAPEAKE BAY**

A comparison of the point and nonpoint source loads was conducted for some of the major tributaries of the Bay: the James, Potomac and Patuxent rivers below the fall line. The organic contaminant data used to make these comparisons for many of the tributaries have a large amount of uncertainty (i.e., point source data), therefore only trace elements (copper, cadmium, and lead) and a subset of the organic data (i.e., PAHs only) will be discussed below for all areas. Total PCB loadings data are not presented due to the uncertainties in the point source data. An illustration of this uncertainty was presented above. In addition, loadings estimates were compiled for one of the three *Regions of Concern* with the most complete loadings data set (Anacostia River) and compared to the three larger rivers.

### *Inputs of Chemical Contaminants to the James, Potomac, and Patuxent Rivers*

***Summary: Sources of metals to the major tidal rivers are variable.***

***Urban runoff is the dominant source of metals loads to the Patuxent River.***

***Upstream sources of metals loads are dominant in the Potomac and James Rivers.***

***Urban runoff is a substantial source of PAHs to the tidal James, Patuxent, and Potomac Rivers.***

***Point sources of organic contaminants (PAHs, and PCBs) are highly uncertain and therefore loads to the James, Patuxent, and Potomac Rivers are largely unknown.***

## **James River**

### Metals

Trace element loads to the tidal James River range from 9,400 lb/yr for cadmium to 110,000 lb/yr for copper (Figures 8.14-8.16). Fall line loads are the dominant source of metals to the tidal James River. Point sources loads for copper and cadmium account for 11,000 lb/yr (11% of the total load) and 1,600 lb/yr (17% of the total load), respectively. Urban runoff sources for all metals account for approximately 11 to 16% of the total load to the tidal river.

### Polycyclic Aromatic Hydrocarbons (PAHs)

For the PAHs, benzo[a]pyrene and phenanthrene, urban runoff and to a lesser degree, either atmospheric deposition or fall line inputs, are major sources of PAHs to the river (Figures 8.17-8.18). Point source loads estimates of PAHs are highly uncertain as indicated by the large uncertainty bars in the figures. Virtually all of the measurements of PAHs were below the detection limit. Therefore the point source loads could range anywhere between zero to the product of the detection limit and flow. Therefore, the point source loads of PAHs are unknown and the data presented in the figures are of limited use. Urban runoff accounts for approximately 4 to 6% of the total input of PAHs to the tidal Bay. Given that point source loads estimates are highly uncertain, the relative contribution of urban runoff is substantially greater than initially estimated.

### **Potomac River**

#### Metals

Loads of trace metals to the tidal Potomac River range from 2,300 lb/yr for cadmium to approximately 160,000 lb/yr for lead (Figures 8.19-8.21). Fall line loads are the dominant source to the tidal river, comprising greater than 75% of the total load. Average point source loads for copper, 17,000 lb/yr, account for 11 % of the total load with lesser amounts for cadmium and lead. Urban runoff from the tidal watershed to the river accounts for between 7% for cadmium and 14% of the total load for lead. Atmospheric inputs, direct to the tidal water, are small and generally less than 3% for all metals with the largest load of 3,400 lb/yr for lead (2% of the total load).

### Polycyclic Aromatic Hydrocarbons (PAHs)

As with the James River, the PAH (benzo[a]pyrene and phenanthrene) loads are dominated by point sources although the data is very uncertain (Figures 8.22-8.23). Urban runoff and to a lesser degree, either atmospheric deposition or fall line inputs, are major sources of PAHs to the river.

### **Patuxent River**

#### Metals

In contrast to the James and Potomac rivers, loads to the tidal Patuxent River for all metals are dominated by urban runoff. Inputs of metals ranged from 390 lb/yr for cadmium to 4,200 lb/yr for copper (Figure 8.24-8.26). Urban runoff accounts for between 44 to 51% of the total tidal input for copper and cadmium, respectively to 66% for lead. Inputs from the non-tidal portion of the watershed (i.e., fall line) are substantial for copper (37% of the total) and smaller 9

### Comparative Loadings in the Bay

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to 23% of the total load for cadmium and lead, respectively (Figures 8.24-8.26). Deposition to the tidal waters of the river accounts for between 10% for Cu and Zn to approximately 20% for lead. Point source inputs account for a small percentage of the total load (5 to 10% of the total load for all metals).

### Polycyclic Aromatic Hydrocarbons (PAHs)

For the PAHs, benzo[a]pyrene and phenanthrene, the loads are dominated by urban runoff with average loads of 320 and 720 lbs/yr respectively, although there is a large degree of uncertainty as indicated by the range of the estimates (Figure 8.27-8.28). Total and atmospheric deposition and point source loads are a small but important component of the total load to the Patuxent River. Atmospheric deposition loads range from < 1 to 22% of the total load for benzo[a]pyrene and phenanthrene, respectively, and from 4 to 8% of the total load for point source loads of benzo[a]pyrene and phenanthrene.

### *Inputs of Trace Elements to the Anacostia River*

**Summary:**     *Upstream sources of metals are dominant in the Anacostia River, with the second highest load coming from urban runoff and combined sewer overflows.*

The load of contaminants to the Anacostia River, a *Region of Concern*, was compiled from various sources including the data from the previous chapters, MW COG (1997), Velinsky et al. (1996) and Gruessner et al., (1997). These documents describe loadings to the Anacostia River and are part of the Regional Action Plan assessment. It should be noted that upstream sources (i.e., fall line loads) were measured directly over a 1-yr period while the other source categories were estimated from various land use/hydrologic models. Due to the limited data set, as compared to the other, larger tributaries, uncertainties in the loads were not estimated for the Anacostia.

Loads to the tidal Anacostia River were estimated for cadmium, copper, lead, zinc (Figures 8.29-8.32). Since there were insufficient data for other contaminants from all sources, only trace metal loads are presented. Total loads to the tidal waters range from 340 lb/yr for copper to more than 23,000 lb/yr for zinc. Upstream sources dominate the input of these metals, with more than 77% of the total input derived from the non-tidal watershed. Urban runoff or combined sewer overflows (CSO) inputs to the tidal Anacostia River can also be a major source of trace elements. For zinc and lead, combined sewer loads account for between 18% and 23% of the total load to the tidal waters. Urban stormwater runoff loads are variable for these metals (Figures 8.29-8.32). While previous calculations by Velinsky et al. (1996) suggest that urban runoff was a major source of aromatic hydrocarbons to the tidal river, the recent data by Gruessner et al. (1997) indicates that upstream sources could be more substantial. Uncertainties, or ranges, were not reported for Anacostia River loads due to a lack of data from the different data sources. For example, reports for point source and urban runoff loads did not include ranges

and therefore they could not be calculated in this inventory.

### *Watershed Yields*

**Summary:**     *The Anacostia River watershed, a highly urbanized area, produces 3 and 12 times more copper and lead, respectively, per watershed area than any of the major rivers in the Bay watershed.*

*Landuse characteristics in a watershed influences the chemical loadings from a watershed.*

*Loadings are not proportional to the size of the watershed.*

The total watershed yield for specific trace metals was calculated by dividing the total load (lb/yr) for a watershed by its total drainage area (above and below the fall line) for four trace metals (units: lb/km<sup>2</sup>-yr; Table 8.1). This calculation can be used to evaluate if specific watershed characteristics are more important in determining the overall load to the tidal Bay. Land use (i.e., amount of urban area) and point sources could be two important characteristic affecting the yield of a chemical from a watershed area.

Table 8.1. Trace metal total watershed yields for selected tributaries of the Bay.

	Susquehanna	Potomac	James	Patuxent	Anacostia
Cu	4.05	3.90	3.95	1.75	13.1
Cd	0.61	0.61	0.35	0.16	0.46
Pb	2.44	4.17	3.15	1.54	42.9
Hg	0.052	0.084	0.055	0.018	0.026

Units: lb/km<sup>2</sup>-yr.

The watershed yield information suggests that there is no trend between watershed size and area and the load of specific trace metals. For example, the Susquehanna River watershed, the largest in the Bay watershed, did not show the greatest areal yields indicating that watershed area was not directly related to the loads. The copper yield for the Anacostia watershed was higher than other watersheds by a factor ranging between 3 and 6. The Anacostia's lead yield was approximately 12 times higher than the other watersheds. This indicates a higher concentration of copper and lead sources in the Anacostia watershed which most likely originate from urban runoff, illustrating the higher per unit area loads in urban environments. Landuse characteristics are probably more important in determining the load of a contaminant to the Bay. The higher yields for the Anacostia, may be the result of higher urban stormwater sources for many contaminants.

Copper yields were very similar between the Susquehanna, Potomac, and James Rivers, the three largest watersheds in the Bay, while the copper yield for the Patuxent watershed was slightly lower (Table 8.1). Cadmium yields for most watersheds were in good agreement except for the Patuxent watershed in which the total cadmium yield was lower by a factor of 4. Similarly, lead yields for the Susquehanna, Potomac and James watersheds agreed, while the yield for the Patuxent watershed was slightly lower. Mercury yields were similar for the Susquehanna and Potomac watersheds, while slightly lower for the both the Patuxent and Anacostia watersheds. The good agreement for watershed yields for many metals between watersheds suggests a fairly accurate accounting of sources and loads, however, systematic error in data gathering can not be discounted at this time.

## **DISCUSSION AND RECOMMENDATIONS**

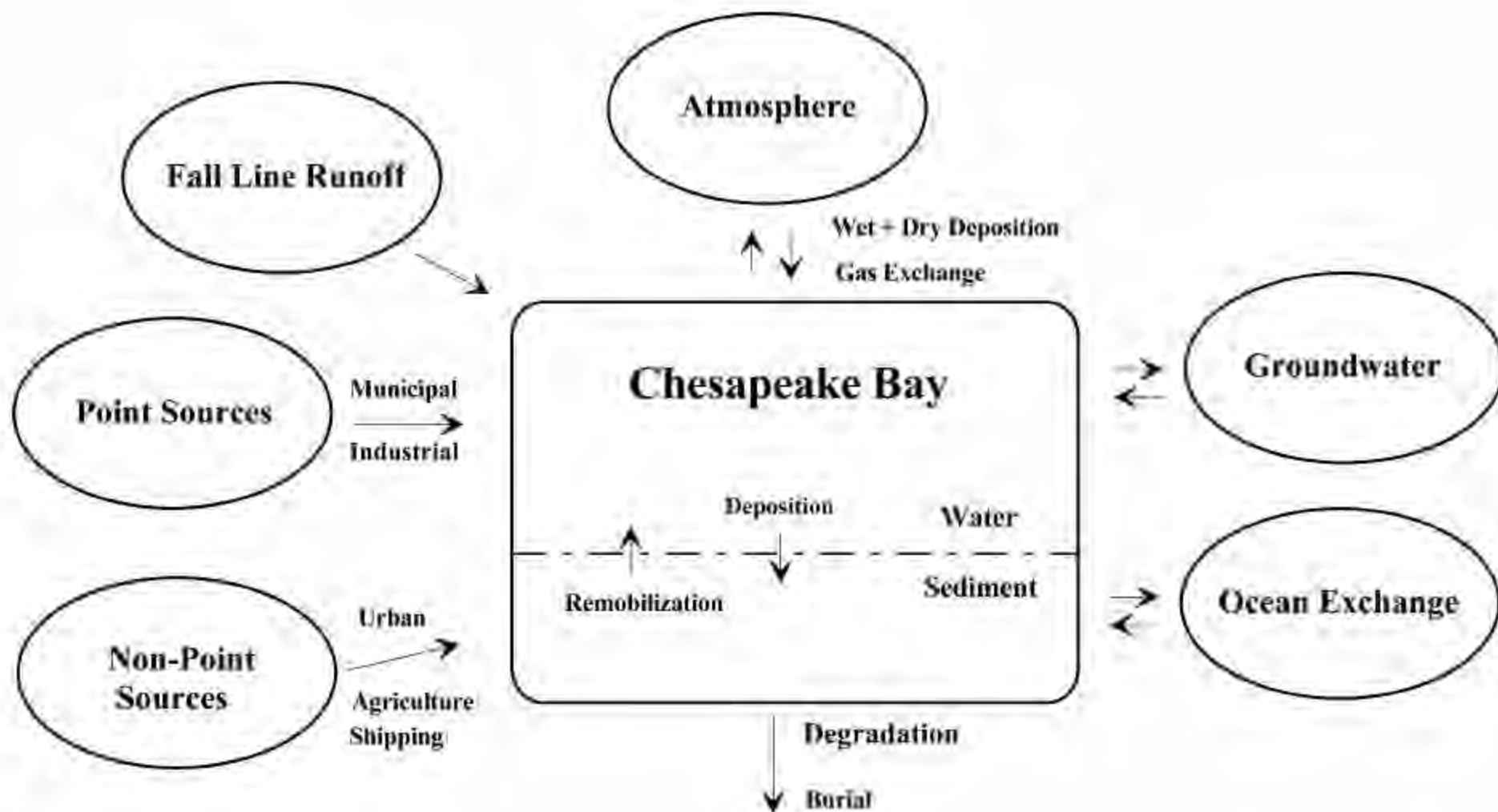
Sources of contaminants to the tidal Bay and specific tributaries varied substantially. Fall line loadings are a substantial source of metals to the tidal Bay and individual rivers such as the Potomac, James, and Anacostia rivers. Point sources are substantial sources for select metals in the tidal Bay. Urban runoff is a substantial source of organic contaminants to the tidal Bay and many of its rivers and a substantial source of metals to the Patuxent river. Point source loads of organic contaminants are largely unknown due to limitations of the data. In the Anacostia, a highly urbanized *Region of Concern*, watershed yields of metals were much higher than in the Susquehanna, Potomac, James, and Patuxent rivers.

To better define the load from point sources specific monitoring efforts are needed throughout the Bay area and specific targeted areas, such as the *Regions of Concern*. This is due to the fact that point sources may be under or overestimated (i.e., detection limits, lack of data). While it would be prohibitively expensive to accurately determine the concentration of specific metals and organic contaminants in every outfall of the Bay, representative discharges could be sampled to provide a Baywide database of typical pollutant concentrations (i.e., TPCs) for specific industrial/municipal facilities. This database could then be used to help augment the statewide monitoring efforts and provide a better information to make loadings summaries. Additionally, more accurate chemical analysis and reporting within the National Pollutant Discharge Elimination System (NPDES) and Permit Compliance System (PCS) programs need to be initiated. Information within the NPDES database is difficult to obtain, not accurately reported (i.e., missing units, decimal points, etc.), and are not accurately analyzed (i.e., laboratory analysis). Historically, the NPDES data was used mainly to determine water quality violations at a facility, not loads. However, with the advent of TMDLs, the NPDES data is now being used to determine loads to specific waterbodies. Unless the laboratory analysis of the NPDES programs and reporting aspects of the PCS improved, loads obtained from this data will be questionable.

Overall, better basic monitoring information is needed for almost all sources identified in this inventory and in each chapter specific recommendations are provided to better quantify each source. To improve upon the loading analysis for future loadings studies, additional information

is needed. The purpose of many of these recommendations is to help provide site specific data that can be applied to other areas of the tidal and non-tidal Bay. As such, studies should focus on representative areas in which the data can be applied to other areas. Recommendations include:

- ▶ For all sources determine a consistent chemical fraction (e.g., total, total recoverable, dissolved).
- ▶ Explore alternate methods such as the typical pollutant concentration method for subsequent updates to the point source inventory for organic contaminants.
- ▶ Use lower detection limit methods for dissolved, particulate or total analyses for point sources and other sources as needed.
- ▶ Improved analysis for organic contaminants for many source functions.
- ▶ Include urban agricultural stations in the atmospheric deposition network as well as stations within specific watersheds.
- ▶ Conduct comprehensive sampling of representative major point source dischargers for specific contaminants using clean methods.
- ▶ Conduct site specific studies (i.e., sampling, analysis, and modeling) to better estimate the urban flux of chemical contaminants.
- ▶ Characterize and determine the source of chemical contaminants within the measured fall line loads (i.e., source allocation, watershed retention).
- ▶ Develop confidence levels and measures of uncertainty for each source category and incorporate into the final loadings analysis.





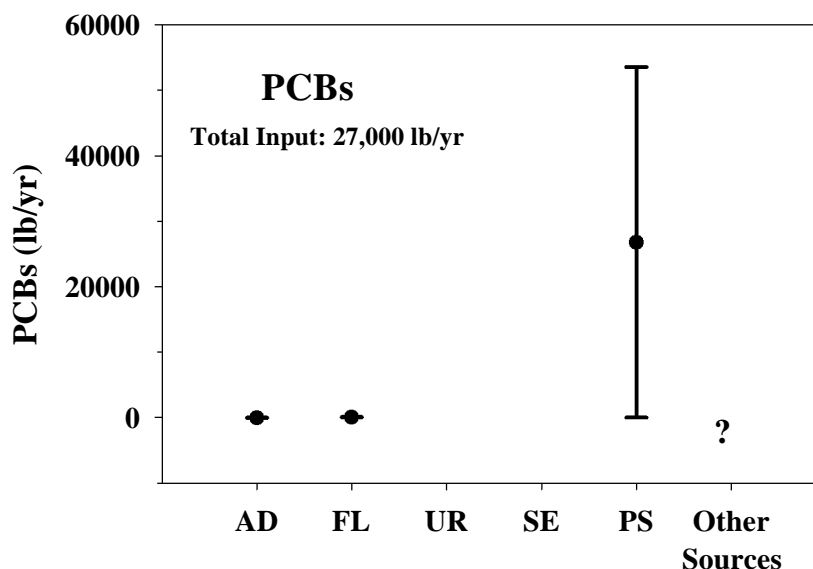


Figure 8.2. Total loads of PCBs to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the atmospheric deposition and fall line estimates is smaller than the symbol representing the average.

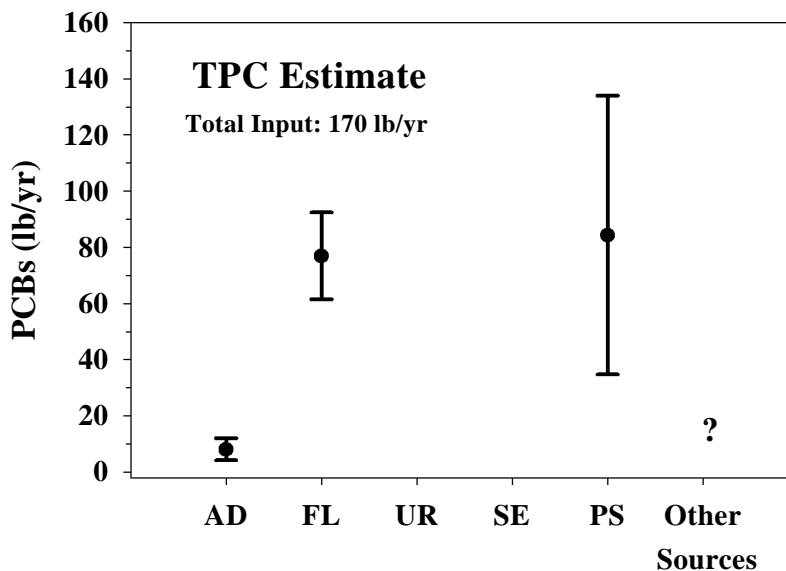


Figure 8.3. Total estimated loads of PCBs to the tidal Potomac River based on typical pollutant concentrations (TPC) from the literature from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

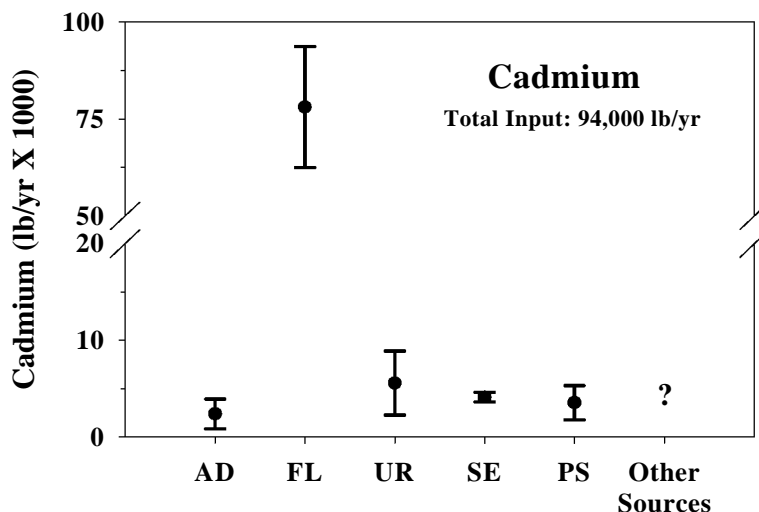


Figure 8.4. Total loads of cadmium to the tidal waters of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

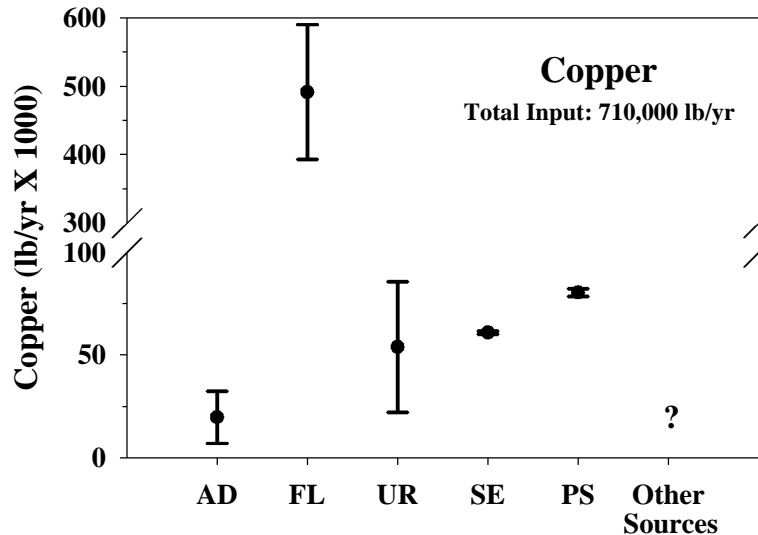


Figure 8.5. Total loads of copper to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the shoreline erosions estimate is smaller than the symbol representing the average.

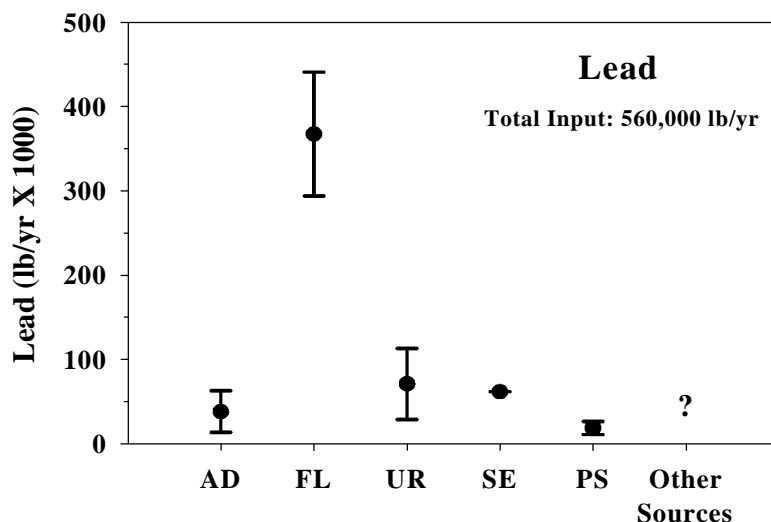


Figure 8.6. Total loads of lead to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the shoreline erosions estimate is smaller than the symbol representing the average.

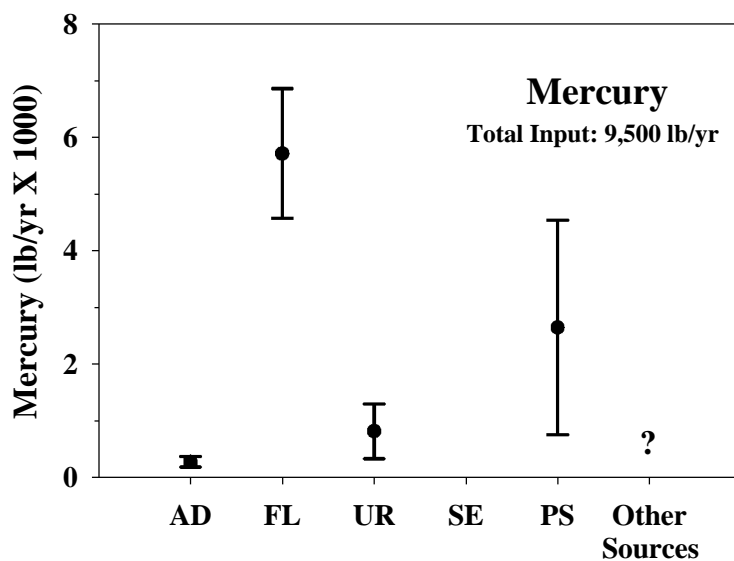


Figure 8.7. Total loads of mercury to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

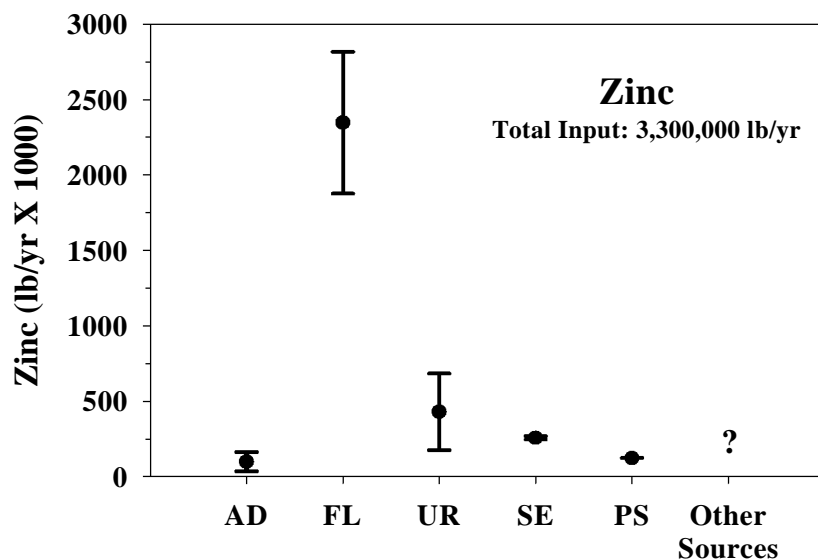


Figure 8.8. Total loads of zinc to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the point source estimate is smaller than the symbol representing the average.

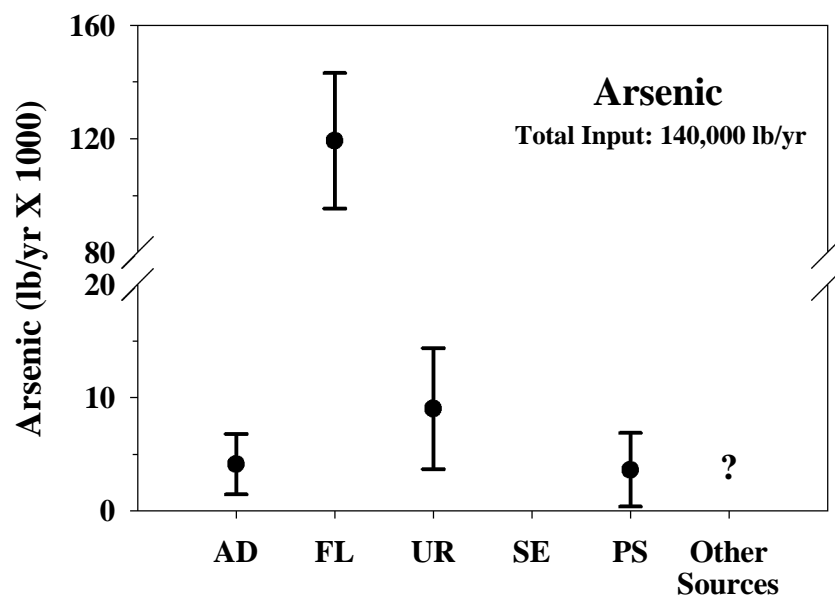


Figure 8.9. Total loads of arsenic to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

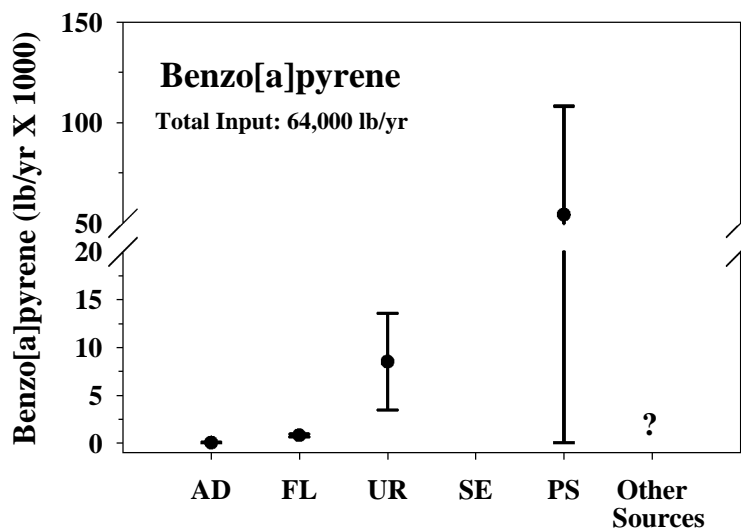


Figure 8.10. Total loads of benzo[a]pyrene to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the atmospheric deposition and fall line estimates is smaller than the symbol representing the average.

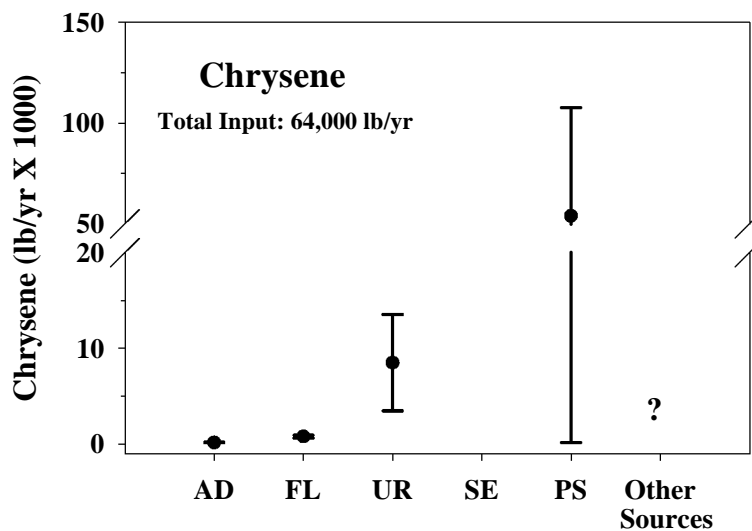


Figure 8.11. Total loads of chrysene to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the atmospheric deposition and fall line estimates is smaller than the symbol representing the average.

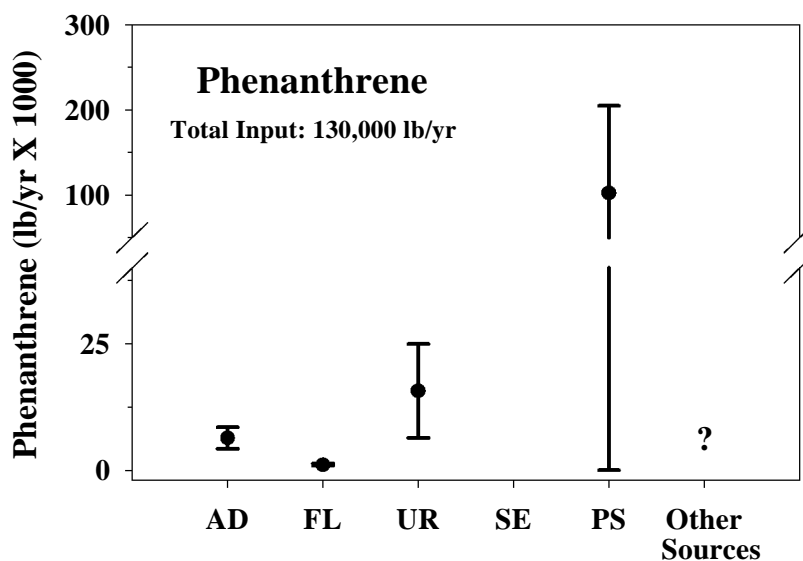


Figure 8.12. Total loads of phenanthrene to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the fall line estimate is smaller than the symbol representing the average.

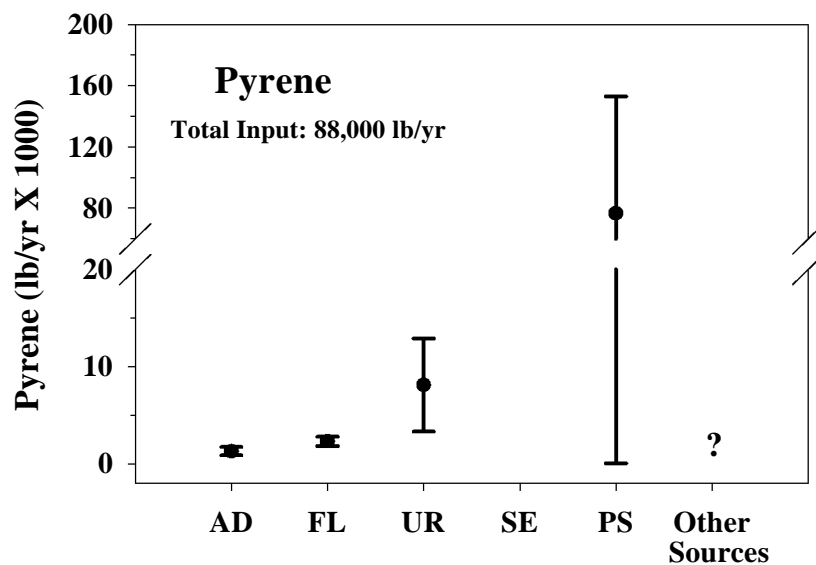


Figure 8.13. Total loads of pyrene to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

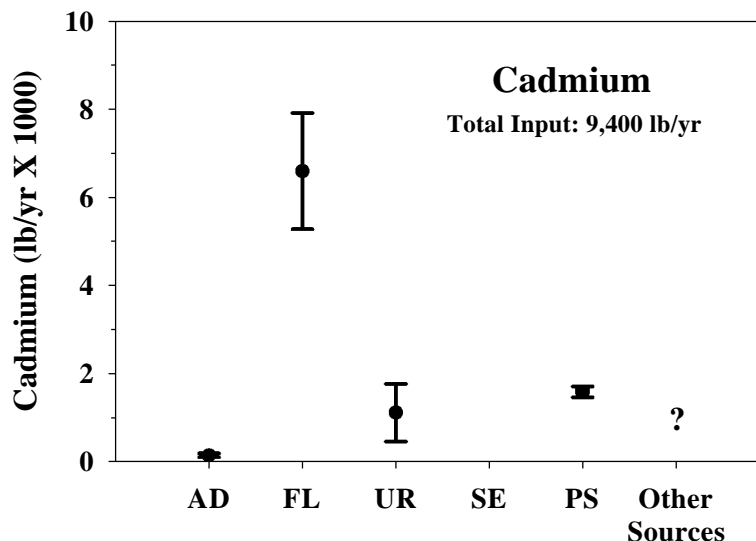


Figure 8.14. Total loads of cadmium to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

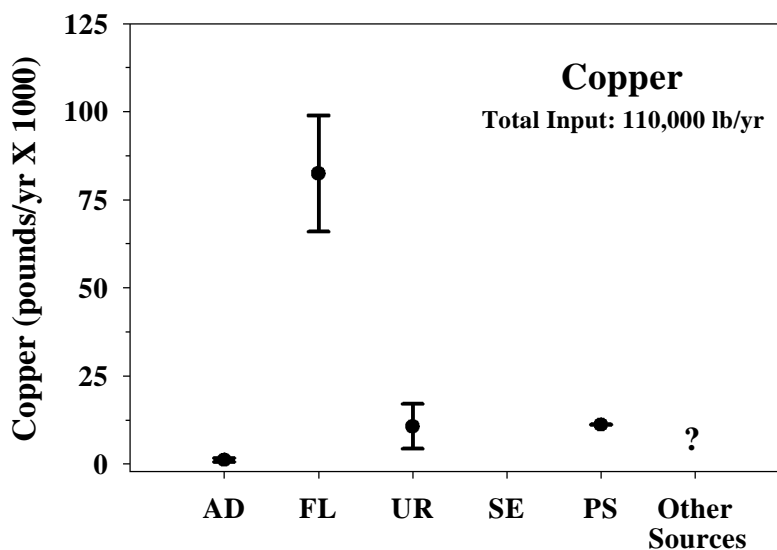


Figure 8.15. Total loads of copper to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the point source estimate is smaller than the symbol representing the average.

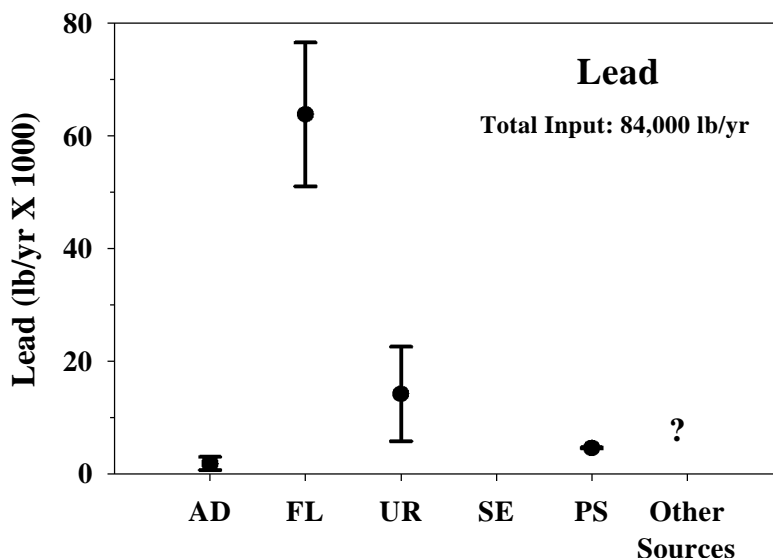


Figure 8.16. Total loads of lead to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the point source estimate is smaller than the symbol representing the average.

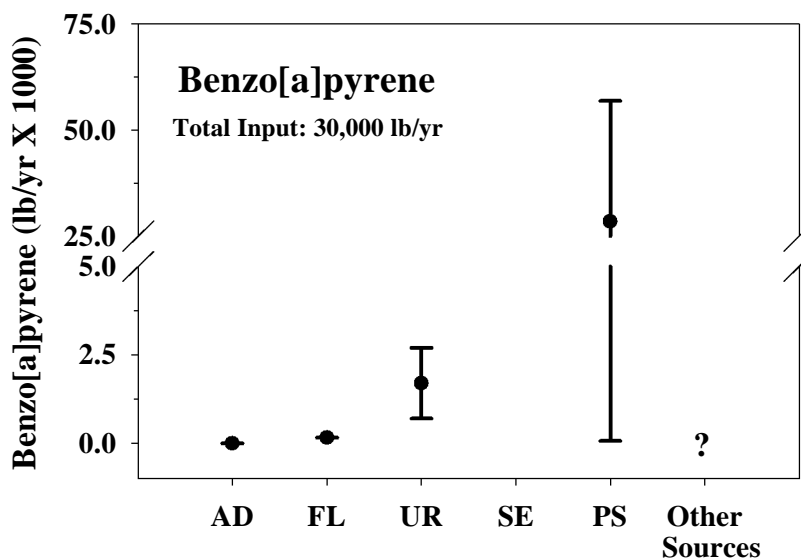


Figure 8.17. Total loads of benzo[a]pyrene to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the atmospheric deposition and fall line estimates is smaller than the symbol representing the average.



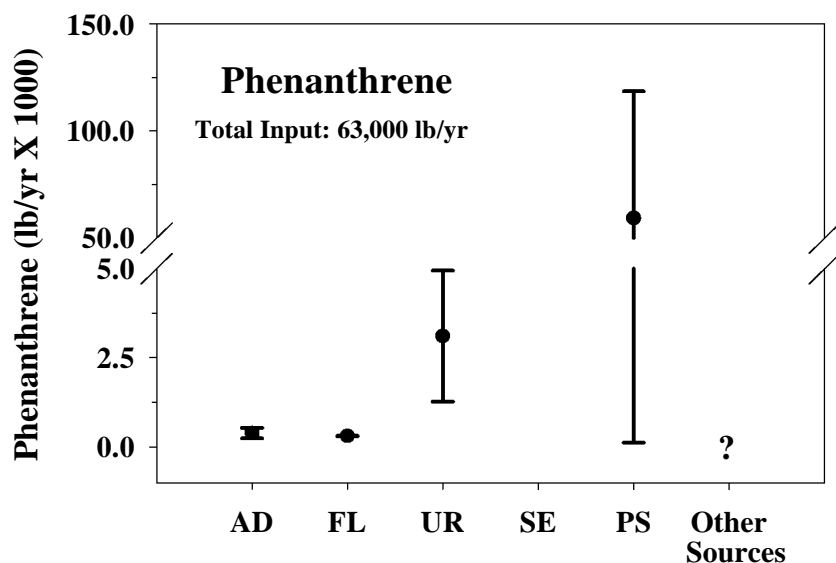


Figure 8.18. Total loads of phenanthrene to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the fall line estimate is smaller than the symbol representing the average.

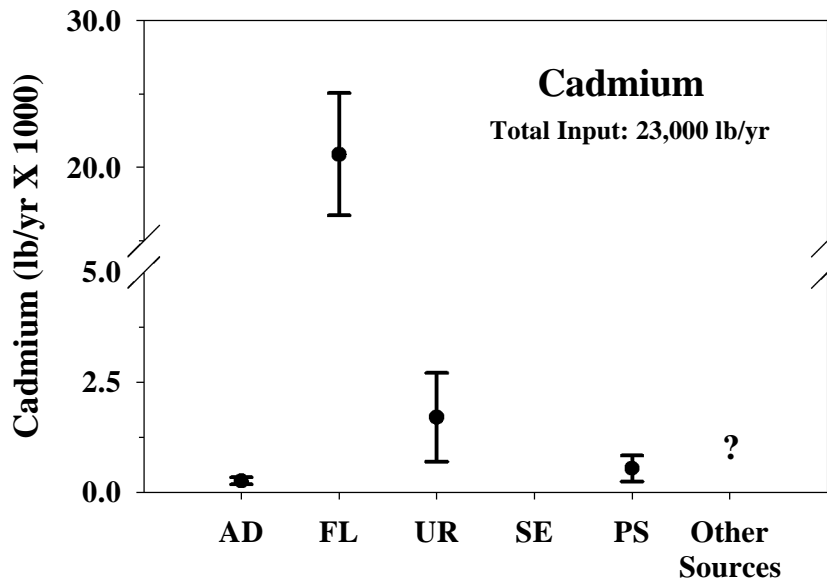


Figure 8.19. Total loads of cadmium to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

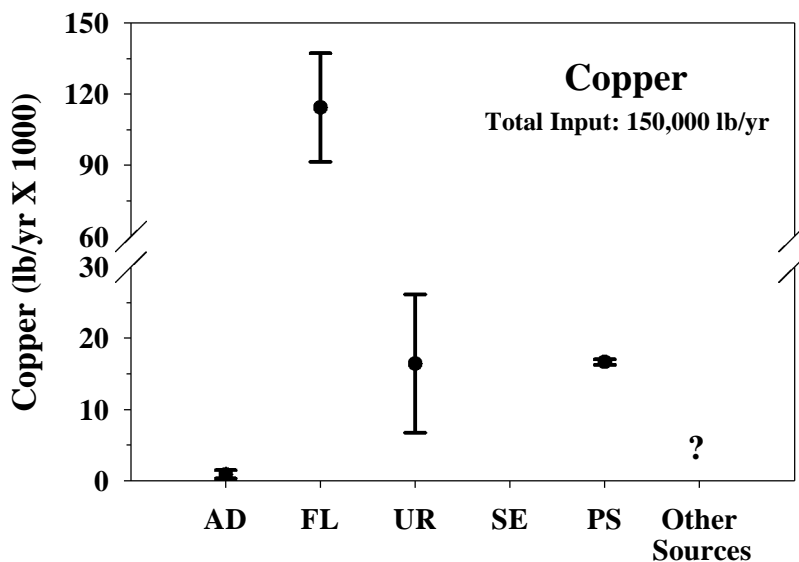


Figure 8.20. Total loads of copper to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

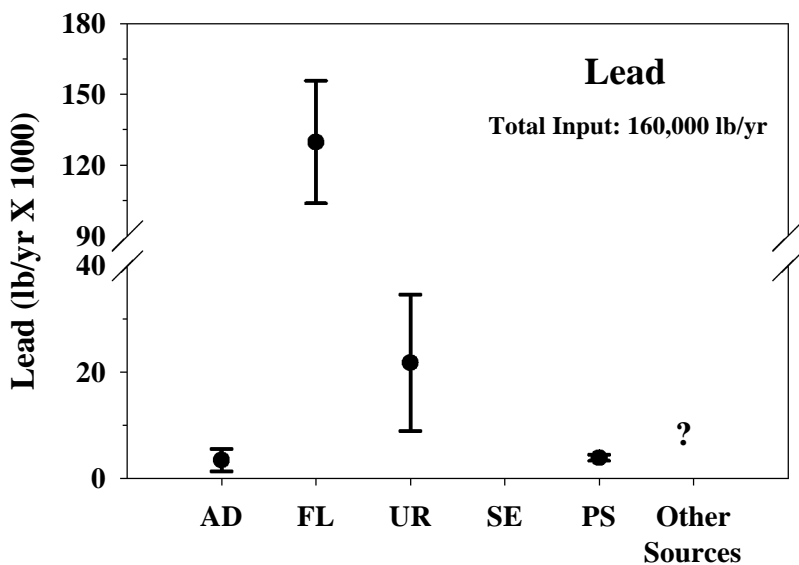


Figure 8.21. Total loads of lead to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

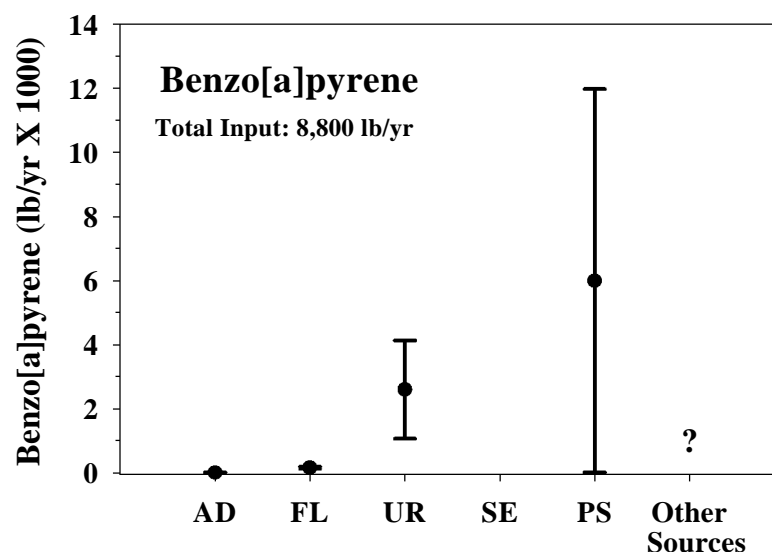


Figure 8.22. Total loads of benzo[a]pyrene to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the atmospheric deposition and fall line estimates is smaller than the symbol representing the average.

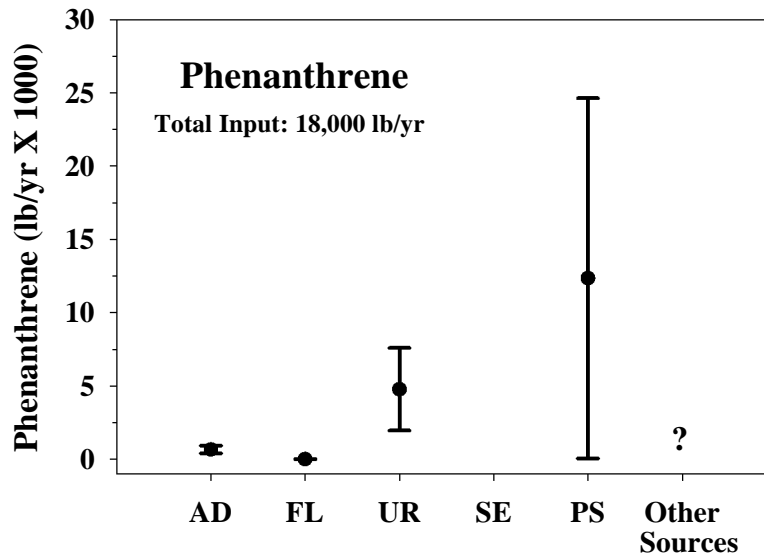


Figure 8.23. Total loads of phenanthrene to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the fall line estimates is smaller than the symbol representing the average.

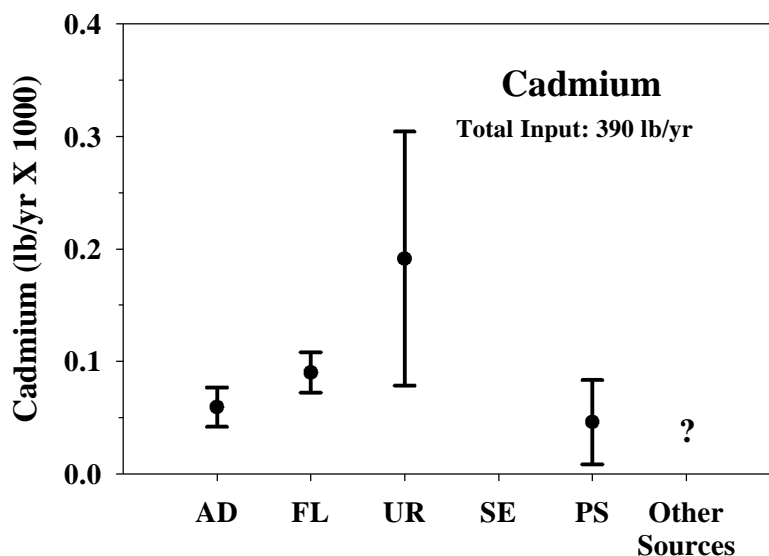


Figure 8.24. Total loads of cadmium to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

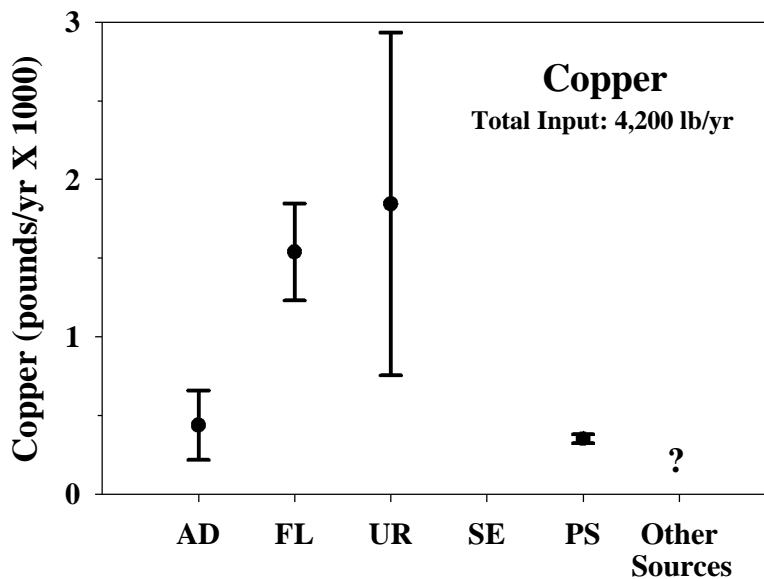


Figure 8.25. Total loads of copper to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

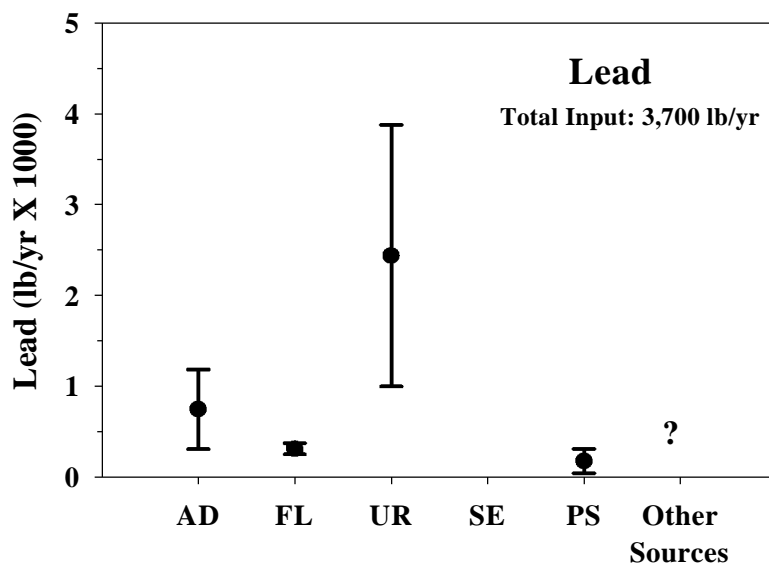


Figure 8.26. Total loads of lead to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources.

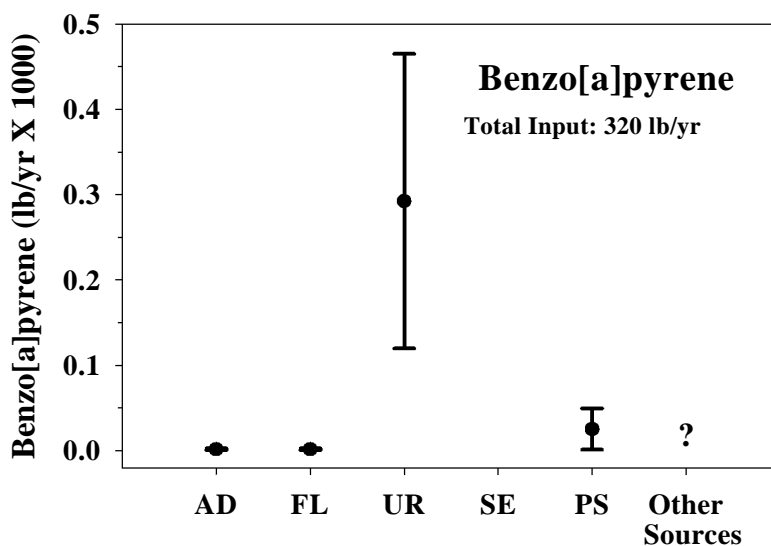


Figure 8.27. Total loads of benzo[a]pyrene to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the atmospheric deposition and fall line estimates is smaller than the symbol representing the average.

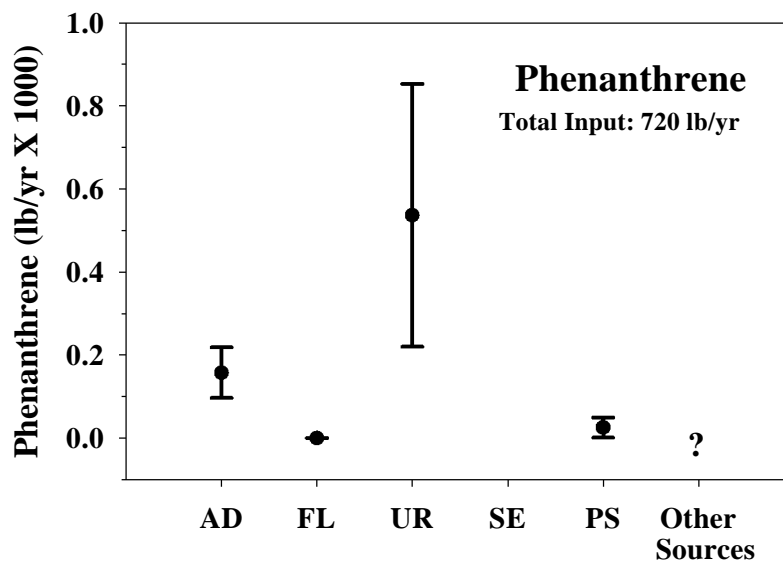


Figure 8.28. Total loads of phenanthrene to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability in the fall line estimates is smaller than the symbol representing the average.

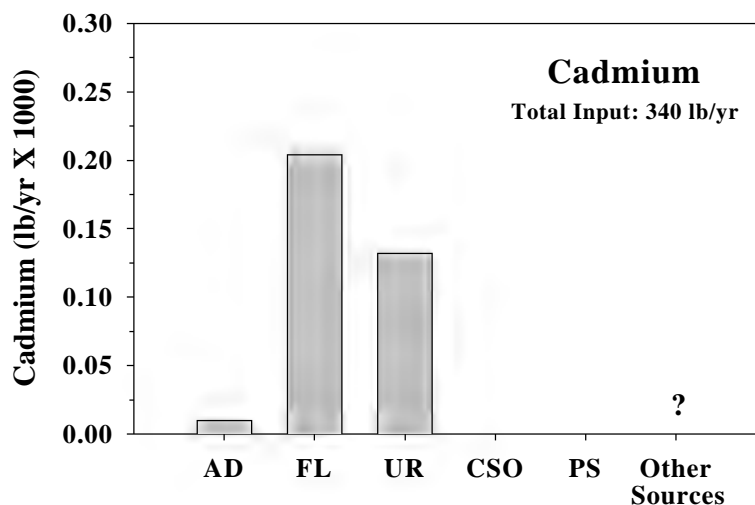


Figure 8.29. Total loads of cadmium to the tidal Anacostia River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); combined sewer overflow (CSO); and point sources (PS). Point source loadings were not reported. Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability was not calculated due to the lack of data and reported ranges.

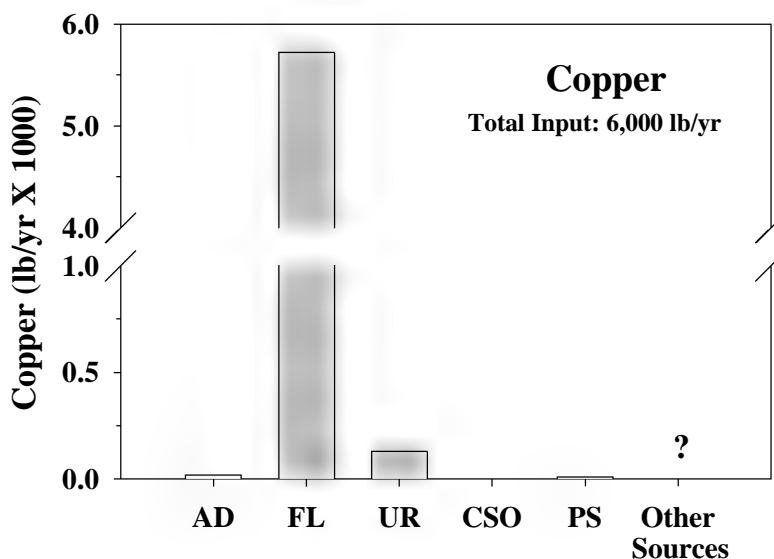


Figure 8.30. Total loads of copper to the tidal Anacostia River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); combined sewer overflow (CSO); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability was not calculated due to the lack of data and reported ranges.

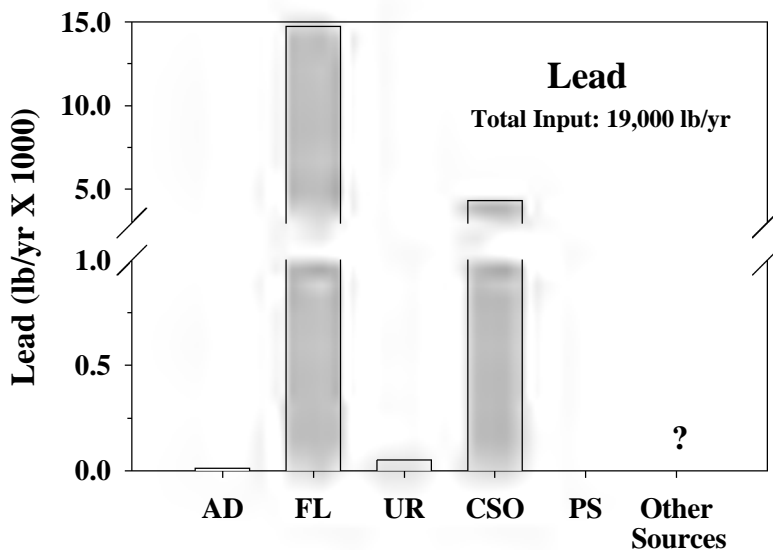


Figure 8.31. Total loads of lead to the tidal Anacostia River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); combined sewer overflow (CSO); and point sources (PS). Point source loadings were not reported. Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability was not calculated due to the lack of data and reported ranges.

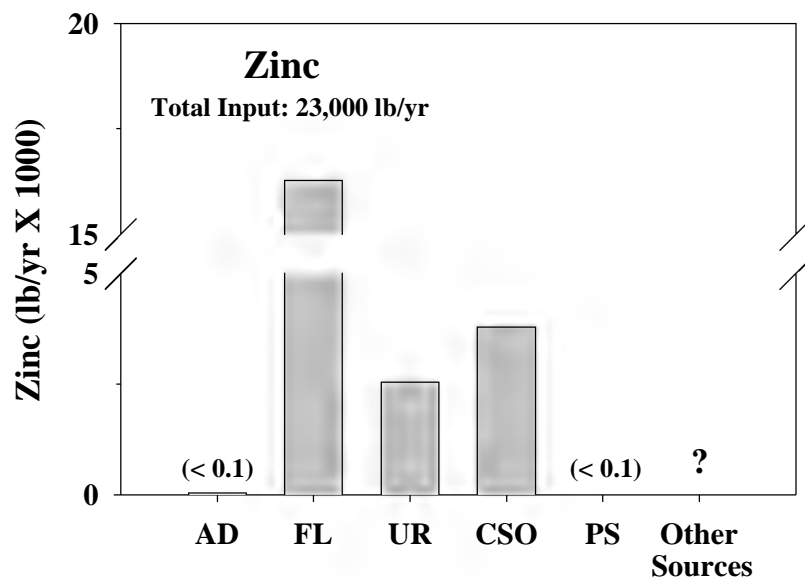


Figure 8.32. Total loads of zinc to the tidal Anacostia River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); combined sewer overflow (CSO); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition, groundwater, and natural sources. The variability was not calculated due to the lack of data and reported ranges.



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## CHAPTER 9 - Mass Balance of Chemical Contaminants within Chesapeake Bay

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### INTRODUCTION

The *Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report* (Chesapeake Bay Program, 1994b) described the results of a multi-year effort to evaluate the nature, extent, and magnitude of the Bay's chemical contaminant problems. Continuing these efforts, the data within the preceding chapters present recent information regarding the various measured and potential inputs to the Bay. While these studies continue the Bay Program's effort to account for the sources of chemical contaminants, a more exacting examination of *both* the sources (inputs) and sinks (outputs) is needed. The identification and quantification of the different sources and sinks of anthropogenic chemicals in Chesapeake Bay is an important step towards understanding their cycling and potential effects, and can help target strategies for contaminant reductions.

One way to place this information into a coherent framework, or accounting system, is to develop chemical contaminant mass balances (Velinsky, 1997). A mass balance requires that the quantities of chemical contaminants entering the Bay, less the amount stored, transformed, or degraded within the system, equal the amount leaving the Bay system. With a working mass balance budget, various control strategies can be simulated to evaluate long-term changes for each contaminant or for contaminant groups. Such simulations and predictions can be valuable in the assessment of the effect of chemical contaminants on ecosystem health, and can help make expensive monitoring programs within the Bay more cost-effective. Once a mass balance is accurately verified, it could be used to answer "what if" questions such as; if specific sources are reduced, how much reduction is needed and how long will it take to lower the concentration of a specific contaminant in the water column or an organism to a given level?

A mass balance framework is a useful system in understanding the inputs, outputs and flow of chemical contaminants in the Bay and tributaries. Specifically, a mass balance provides: 1) a gross check and balance on whether or not loadings estimates are consistent and realistic, 2) an idea of the fate of contaminants in the Bay and its tributaries, 3) a management tool for predicting results from load reductions, and 4) a consistent way to identify key data gaps and uncertainties that need to be addressed for management/scientific purposes.

This chapter presents an initial test of a simple chemical contaminant mass balance for Chesapeake Bay. This mass balance utilizes data obtained from the preceding chapters and information obtained from the Solomons Island Mass Balance Workshop (May 7&8, 1998). The overall objective of this exercise is to help verify the loads estimated for the Bay. An inherent problem with the current load estimates is that they are of varying accuracy and precision, and are integrated over different spatial and temporal scales. A second problem is that an independent reality check for the loading estimates is lacking. This initial mass balance is used to help compare and evaluate the loading estimates in the Toxics Loadings and Release Inventory (TLRI). However, major differences (i.e., > 10X) between inputs and outputs of a given contaminant likely indicate problems with one or the other estimates, or both.

### Model Framework

The mass balance model used in this study is designed to be as simple as possible while maintaining the extreme spatial variability (i.e., salinity, chemical concentrations, etc.) of the mainstem of the Chesapeake Bay. This is a very simple model, and is not meant to represent the state-of-the-art in water quality modeling. Rather, it is an initial attempt to organize the chemical contaminant loading data within the context of measured ambient levels and estimated contaminant loss processes. This effort describes the spatial variability on scales of tens of

kilometers and on an annual time scale.

This model allows us to compare the loadings described in the preceding chapters to net loss processes, and also to estimate the transport of chemicals from the tributaries to the mainstem of the Chesapeake Bay. The model takes the input of contaminants from the mouth of each tributary (i.e., the boundary between the mainstem bay and a tributary), along with other loadings direct to the mainstem (i.e., atmospheric deposition, point sources, etc.), transports them through the Bay, allowing for burial, degradation, volatilization between the air/sea interface, and sediment burial.

The model is based on a salt-balance model developed by Hagy (1998). The mainstem is divided horizontally into nine boxes (numbered 1-9 from south to north), with all but the northern-most box further subdivided by depth into a surface and bottom layers (Figure 9.1). Water

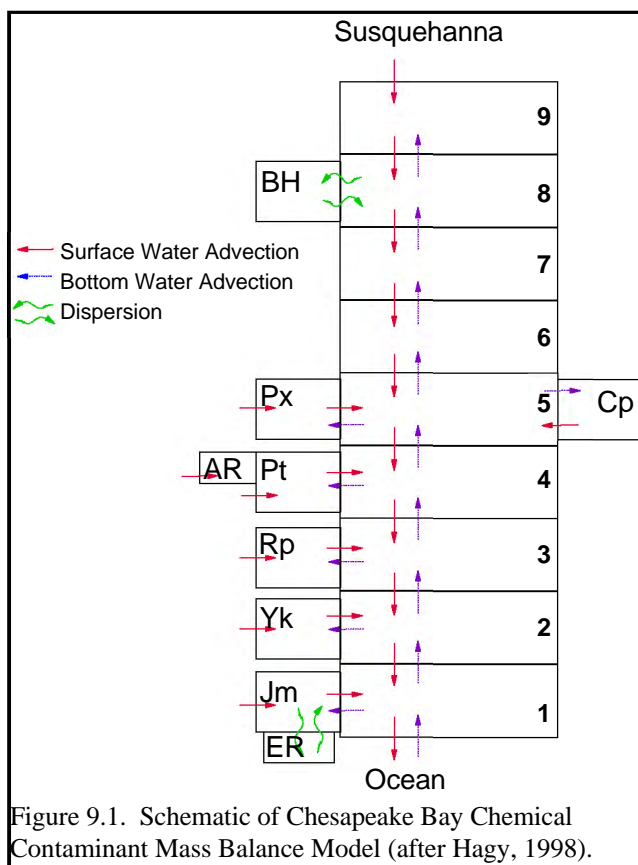


Figure 9.1. Schematic of Chesapeake Bay Chemical Contaminant Mass Balance Model (after Hagy, 1998).

exchanges between these 17 model cells were calculated by Hagy by balancing water flows to match the salinity profiles determined by the Chesapeake Bay monitoring program. Similarly, transport of solids among the boxes depends upon the water flows and the observed suspended solids concentrations in the mainstem. Tributary flows entering the mainstem model boxes were determined by the long-term flow and suspended solids records at the respective tributary gauging stations.

Tributaries are not explicitly modeled here, but rather are treated as single boxes which process loadings and export chemicals to the mainstem at the boundary between the tributary and mainstem boxes. It is important to remember that this model does not properly describe the dynamics of contaminant movements within each tributary. This constraint results from the lack of spatially-explicit concentration data within the tributaries and because the salt-balance approach breaks down in the fresher reaches of the tributaries. There is no explicit linkage between contaminant loadings to the tributaries (which are simply totaled and reported by the model) and the net exports from the tributary (which are calculated as the product of the net water outflow and the estimated ambient chemical concentrations at the mouth of each river).

Chemical contaminants enter and leave each model cell by a variety of processes (Figure 9.2). Chemical inputs to each model segment or cell include those sources cataloged in the previous chapters of this report as well as flows of chemicals from adjacent model cells and exchange with the sediments (resuspension and burial).

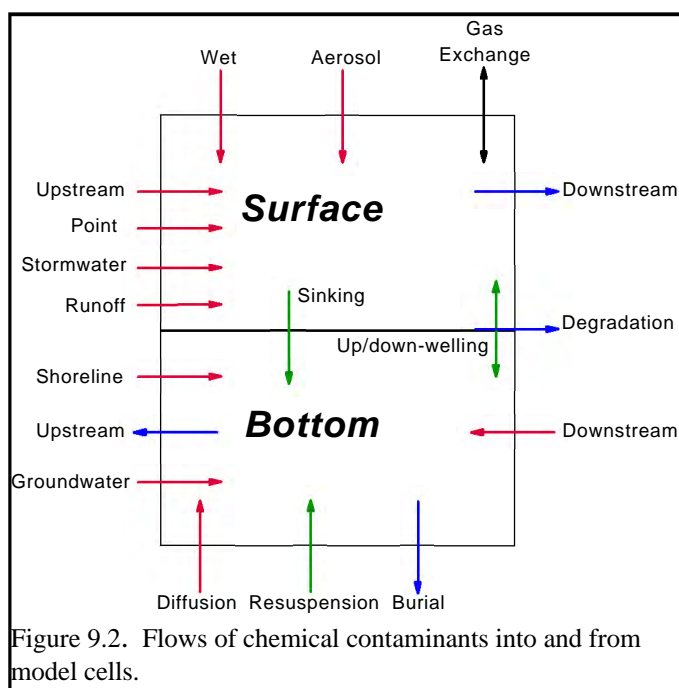


Figure 9.2. Flows of chemical contaminants into and from model cells.

Chemical inputs to each model segment or cell include those sources cataloged in the previous chapters of this report as well as flows of chemicals from adjacent model cells and exchange with the sediments (resuspension and burial). Gross advective transport between adjacent cells is calculated as the product of the estimated concentration of the chemical in the cell ( $\text{g}/\text{m}^3$ ) and the water transport flux ( $\text{m}^3/\text{day}$ ) estimated from the salt balance and the tributary flows. The sinking flux which transports chemicals from surface to bottom model cells is calculated in two steps. First, the concentration of particle-associated chemical contaminant in the surface cell is calculated as a fraction of the total (dissolved plus particulate) concentration using an estimated distribution coefficient and the measured suspended solids concentration. This particle-associated chemical contaminant concentration ( $\text{g}/\text{m}^3$ ) is then multiplied by a 'settling velocity' term (equal to 1  $\text{m}/\text{day}$  in this model) and the interfacial area ( $\text{m}^2$ ) to estimate the settling flux ( $\text{g}/\text{day}$ ). Long-term net rates of chemical burial in sediments is calculated as the product of the measured (or interpolated)

chemical concentration in surficial sediments and the long-term net sediment accumulation rate estimated from measured sediment accretion rates. The bottom of each model cell is the boundary between bottom waters and sediments. Diffusion of chemicals from the sediments are estimated from field and laboratory flux chamber experiments for metals; diffusional fluxes for organic chemicals are assumed to be zero. Resuspension is considered to be a chemical recycling process within the water column (which, therefore, does not affect the mass balance on each model cell), and is calculated as the difference between calculated settling and long term burial rates.

The model calculates chemical flows into and from each model cell on a monthly basis, assuming constant daily flows within each month. All observations were either aggregated (in the case of more frequent measurements such as tributary flows) or disaggregated (in the case, for example, of loadings that were reported on an annual basis) to provide the average daily value for each month. Results from the monthly budgets for each cell were aggregated to produce annual summaries of loadings and losses to the mainstem Chesapeake Bay.

It is very important to remember that this ‘mass balance’ does not require that the loadings and losses of each chemical ‘balance’. That is, the model does not ‘force’ a balance, and no loading or loss term is calculated by difference in order to create a balance. In fact, there is no reason to suspect that the Chesapeake Bay is at steady state with respect to chemical loadings, and it is entirely reasonable to expect that loads do not equal losses. The model simply converts all of the loading terms to the same units and temporal scale and sums them. This is compared to our best estimate of total contaminant losses in the mainstem. Major (i.e., order of magnitude) discrepancies between loadings and losses of a given contaminant, however, likely indicate problems with one or the other estimates, or both.

## **RESULTS AND DISCUSSION**

### ***Trace Elements***

Below are two examples of the model for copper (Cu) and mercury (Hg).

#### **Copper**

Point source, fall line, urban stormwater, atmospheric deposition, and shoreline erosion inputs to the Bay and its tributaries were derived from the information within the preceding chapters. Sediment diffusion of copper out of the sediments was obtained from studies and unpublished data by Riedel et al. (1995a,b;1997; 1999a,b; unpublished data), Cornwall et al. (unpublished data), and others. For copper as well as other metals there is a lack of sediment diffusion data for most areas of Chesapeake Bay and its tributaries. Studies were conducted with Baltimore Harbor, Mid-Chesapeake Bay (Site M), and Patuxent River sediments; either in the laboratory or *in-situ*. The limited data were used along with best professional judgement to derive rates for the mainstem Bay and tributaries. It should be noted that the sediment diffusion

flux of copper to the bottom waters of the Bay is an internal source, and does not affect the assessment of the overall input/output budget within the current model framework.

Accurate concentrations of dissolved copper in the water column throughout the Bay were limited, and there was no information for particulate copper for the mainstem or many tributaries of the Bay. Dissolved data were obtained from the studies of Culberson and Church (1988), Donat et al. (1994; unpublished data), Henry and Donat (1996), Donat and Henry (1997), and for the Patuxent and Anacostia Rivers from Riedel et al. (1995a,b;1997; 1999a,b; unpublished data), Velinsky et al. (1999), and Coffin et al. (1998). The dissolved copper concentrations in the mainstem Bay covered a 10 year period from the work by Culberson and Church (1988) to Donat (1994; unpublished data), Henry and Donat (1996), and Donat and Henry (1997), however, for the current model framework total concentrations of copper are needed. Since there was no particulate (or total) copper concentrations, an average copper partition coefficient (i.e.,  $K_d$  [L/kg = conc. in dissolved phase/conc. in particulate phase]) was derived using the Patuxent River copper data set (Riedel and Gilmour, unpublished data) with varying salinities. The Patuxent River copper  $K_d$  values were used for each segment of the model.

Concentrations of copper in the surface sediments of Chesapeake Bay and its tributaries were obtained from the comprehensive report by Eskin et al. (1996). The data within the report represents surface sediment concentrations from samples collected over various years. Each segment was assigned a median or average concentration for the entire area of the segment. While median or average concentrations were used to calculate the burial of trace metals, there is substantial spatial variability in the concentration of metals throughout all areas. Additionally, as stated above, deposition rates were assumed to cover the entire area of each segment (see Officer et al, 1984). This would tend to overestimate the total deposition to the sediment due to the spatial variations in deposition within each box or area of the mainstem bay.

The total copper load to the mainstem Bay is approximately 118,000 kg/yr (Table 9.1) and indicates that approximately 60% of the total input to the tidal Bay (322,000 kg/yr) is retained within the tributaries. In other words, a substantial portion of the total load to the entire Chesapeake Bay is retained within the tributaries with approximately 40% of the total input transferred to the mainstem Bay. Tributary inputs and shoreline erosion account for major input to the mainstem Bay; approximately 90% of the total input, while direct atmospheric (wet+dry) and point sources are small and total approximately <1% of the total mainstem load. Due to a lack of data, the flux of sediment and associated copper from shoreline erosion was assumed to be to the mainstem Bay, and this is probably an overestimation given the extensive shoreline in the tributaries and potential erosion.

The main mechanism for the loss of copper from the mainstem Bay is sediment burial with only a small fraction exchanging out the Bay mouth to the coastal waters (Table 9.2). The total output from the mainstem was calculated to be 110,000 kg/yr which is in excellent

## ***Mass Balance***

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agreement with the total input to the mainstem Bay. Given the uncertainty in the modeling framework and assumptions for various input/output rates (i.e., flows, sedimentation rates, etc), it is remarkable that a good balance was obtained and suggests that the inputs to the Bay are fairly well constrained. The loss of copper via burial (105,000 kg/yr) is a net rate with sediment diffusion re-releasing approximately 20,000 kg Cu/yr back into the mainstem Bay.

In summary, the present mass balance estimate within Chesapeake Bay for copper appears to be fairly well constrained. While there is a good agreement between the sources of copper and removal of copper, better quantification of the tributary inputs (i.e., the boundary between the tributaries and the mainstem) and sediment burial are needed. These along with the Susquehanna River inputs are the major fluxes identified by the model. The majority of the copper loads to the mainstem Bay is from Susquehanna River with lesser amounts from the tributaries. As stated earlier, shoreline erosion was assumed to be direct to the mainstem Bay. However, given the extensive shoreline and potential erosion in the tributaries the total flux needs to be separated between tributary and mainstem Bay inputs. These areas would help support the agreement between inputs and outputs in the Chesapeake Bay.

### **Mercury**

Loadings of total mercury to the Chesapeake Bay below the fall-lines are summarized in Table 9.3. Estimates of atmospheric deposition (wet deposition, dry aerosol deposition, and net volatilization) and fall-line loadings are taken from the studies of Mason and co-workers (Mason et al., 1997a,b; Lawson and Mason, 1998; Benoit et al., 1998; Mason et al., 1999; Mason and Lawrence, 1999). Mercury loadings from point sources and urban runoff are taken from estimates in the preceding chapters. Erosion of shoreline material is assumed to be an insignificant source of mercury, though whether erosion is an important source of mercury to the Bay is largely unknown. The role of groundwater as a source of mercury to the Bay is also unknown and is assumed to be zero for this exercise. As is the case with the other chemicals analyzed here, point source loadings of mercury were estimated as the average of the 'high' and 'low' estimates taken from Chapter 1.

According to this analysis, tributary and point source inputs contribute the majority of the total mercury loading to the Bay below the fall-lines. The point source loads are likely an overestimation due to analytical methods and detection limit issues with point source effluent analysis. Diffusion from sediments, urban runoff, and inputs from the rivers contribute about 75% of the total mercury load to the mainstem Bay if the point source loads are correct. The majority of the mercury enters the bay in its tributaries below the fall-lines. Virtually all of the urban runoff and point sources of mercury are discharged to the tributaries rather than the mainstem. As was seen with other particle-reactive chemicals, the vast majority of the mercury discharged into the tributaries is retained and not transmitted to the mainstem. Less than 10% of the mercury that enters the tributaries is transmitted into the mainstem of the Chesapeake Bay. Although we do not have sufficient data from the tributaries to verify these estimates of mercury retention, this calculation suggests that localized tributary sediments should be enriched in

mercury and other particle-reactive contaminants.

Losses of mercury from the mainstem Chesapeake Bay include export to the ocean, burial in sediments, and volatilization (Table 9.4). In this analysis, burial accounts for three quarters of the mercury loss, with export and volatilization resulting in 20% and 3% of the annual mercury loss, respectively. The estimated total annual losses of mercury from the mainstem Chesapeake are four times the estimated loadings to the mainstem. Whether this discrepancy reflects a real imbalance between loads and losses or indicates over- and/or underestimations of sources and sinks cannot be determined from these data.

### *Organic Contaminants*

Below are two examples of the mass balance calculations for organic contaminants presented using total PCBs (sum of all measured congeners or, in the case of point source loadings, Aroclor 1260) and the polycyclic aromatic hydrocarbon (PAH) phenanthrene.

#### Total PCBs

Total PCB loadings were calculated for each source type as described in the preceding chapters (Table 9.5). As no estimate of PCB loadings from urban runoff were made, we assumed here that the PCB load was equal to one half of the total mercury load from urban runoff, based on our recent observations that the concentrations of total PCBs in the water column and sediments of an urban-runoff dominated system (i.e., Baltimore Harbor) are approximately one half those of mercury (Ashley et al., 1999; Mason and Lawrence, 1999). Transport of total PCBs from the tributaries to the mainstem was estimated for each tributary assuming a total PCB concentration at the river mouths of 0.95 to 1.2 ng/L (Nelson et al., 1998).

The comparison of loadings of total PCBs to the Chesapeake Bay below the fall lines shows that estimated point sources are three orders of magnitude greater than all other sources (Table 9.1) and this is certainly not correct. In fact, the estimated point source loadings of PCBs far exceed our best estimate of the amount of PCBs in the mainstem Chesapeake Bay (perhaps on the order of 1,000 kg total in the water column and sediments). Even if the point source estimate is 100 fold too high, however, we still conclude that point source emissions of PCBs is an important contribution to the total loading. This was illustrated by the Potomac River point source data described in the previous chapter. In this example, point source concentrations of total PCBs were derived from recent studies in the Delaware and Hudson Rivers and used with the flow from point sources to the tidal Potomac River. The resultant load indicates that approximately 60% of the total PCB load is derived from point sources and PCB loads are comparable to fall line estimates to the tidal Potomac. In the current analysis, virtually all of the PCBs entering the Chesapeake Bay are loaded into the tributaries. The estimate for the total PCB loading to the mainstem of the Chesapeake Bay is 183 kg/year, one third of which is supplied by loading from the Susquehanna River. Urban runoff and atmospheric deposition supply approximately equal loads of PCBs to the mainstem Chesapeake Bay.

It is crucial to note that a vanishingly small fraction of the PCB loading to the tributaries is transported to the mainstem Chesapeake Bay (< 0.5% of 410,000 kg/year.). Even excluding the admittedly flawed point source estimate from the comparison, only 5% of the non-point source loads to the tributaries are transported to the mainstem. This implies that tributaries are extremely efficient traps for these particle-reactive chemicals and that dilution by downstream transport is not an effective cleansing mechanism for the tributaries. Stated another way, these simple calculations support the observation of higher concentrations in the Chesapeake Bay tributaries, where local chemical loadings remain concentrated near discharge points (i.e., point and non-point sources).

Interestingly, the estimates of PCB loadings to the mainstem are six times less than our estimates of PCB losses from the mainstem. Losses of PCBs are distributed among ocean export (50%), volatilization (30%) and burial (20%; Table 9.6). Some fraction of this difference may be real, as the inventories of PCBs in the bay are likely decreasing with time (i.e., losses exceed loadings) in response to the production and use ban on PCBs in the late 1970's. Also, these calculations do not include any net release of PCBs from sediments. A net release on the order of  $180 \mu\text{g}/\text{m}^2\text{-year}$  from the sediments would be required to balance loads and losses; this is about 3.5 times the long-term PCB burial rate.

### **Phenanthrene**

Loadings of phenanthrene to the Chesapeake Bay are summarized in Table 9.7. Unlike PCBs, where volatilization exceeds wet and dry aerosol deposition, absorption of gaseous phenanthrene from the atmosphere is a significant source to the Bay (Nelson et al., 1998; Bamford et al., 1999). Point sources, as estimated in this report, comprise three quarters of the total phenanthrene loading to the Bay below the fall lines, while gas absorption and urban runoff contribute most of the phenanthrene entering the mainstem of the Bay. Approximately 90% of phenanthrene entering the Chesapeake Bay is loaded into the tributaries. As was the case of PCBs, only a small fraction of the phenanthrene entering the tributaries (53,000 kg/year) is transported to the mainstem (1250 kg/year, or 0.2%). This inefficient transmission of phenanthrene likely reflects both burial in tributary sediments and degradation near the emission sources. Degradation of phenanthrene in surface waters, primarily *via* photolytic reactions, accounts for two thirds of the loss of phenanthrene from the mainstem, and burial and export to the ocean are approximately equal in magnitude (Table 9.8).

The reader will note that the independent estimates of phenanthrene loading to the mainstem (4,360 kg/year) and losses (4,310 kg/year) agree to within 2%. As with the copper balance, whether this reflects the skill or the luck of the author remains to be determined.



Table 9.1. Loadings of total copper to Chesapeake Bay.

	<b>Total Load Below Fall- Lines</b>	<b>Total Load to Mainstem</b>	<b>Total Load to Tributaries (by difference)</b>
Wet Deposition	4,700	330	4,400
Dry Aerosol Deposition	4,300	430	3,900
Urban Runoff	24,500	7,200	17,300
Point Sources	36,600	330	36,300
Shoreline Erosion	27,700	27,700	0
Groundwater	0	0	0
Tributaries to Bay	224,000	81,700	142,300
<b><i>TOTAL</i></b>	<b>322,000</b>	<b>118,000</b>	<b>204,200</b>

Units: kg/yr

Table 9.2. Losses of total copper from the mainstem Chesapeake Bay.

Export to the Ocean	2,000
Burial in Sediments	105,000
<b><i>TOTAL MAINSTEM LOSSES</i></b>	<b>107,000</b>

Units: kg/yr

## ***Mass Balance***

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Table 9.3. Loadings of Mercury to Chesapeake Bay.

	<b>Total Load Below Fall- Lines</b>	<b>Total Load to Mainstem</b>	<b>Total Load to Tributaries (by difference)</b>
Wet Deposition	105	92	13
Dry Aerosol Deposition	21	17	4
Diffusion from Sediments	240	130	110
Urban Runoff	370	0	370
Point Sources	1,200	3	1,200
Shoreline Erosion	0	0	0
Groundwater	0	0	0
Tributaries to Bay	2,600	180	2,400
<b><i>TOTAL</i></b>	<b>4,540</b>	<b>420</b>	<b>4,120</b>

Units: kg/yr

Table 9.4. Losses of Mercury from the Mainstem Chesapeake Bay.

Export to the Ocean	350
Volatilization	57
Burial in Sediments	1,350
<b><i>TOTAL MAINSTEM LOSSES</i></b>	<b>1,760</b>

Units: kg/yr

Table 9.5. Loadings of total PCBs to Chesapeake Bay.

	<b>Total Load Below Fall- Lines</b>	<b>Total Load to Mainstem</b>	<b>Total Load to Tributaries (by difference)</b>
Wet Deposition	65	27	38
Dry Aerosol Deposition	65	27	38
Urban Runoff	180	55	129
Point Sources	410,000	0	410,000
Tributaries to Bay	130	74	72
<b><i>TOTAL</i></b>	<b>410,400</b>	<b>183</b>	<b>410,300</b>

Units: kg/yr

Table 9.6. Losses of total PCBs from the mainstem Chesapeake Bay.

Export to the Ocean	560
Volatilization	340
Burial in Sediments	280
<b><i>TOTAL MAINSTEM LOSSES</i></b>	<b>1,180</b>

Units: kg/yr

## ***Mass Balance***

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Table 9.7. Loadings of Phenanthrene to Chesapeake Bay.

	<b>Total Load Below Fall- Lines</b>	<b>Total Load to Mainstem</b>	<b>Total Load to Tributaries (by difference)</b>
Wet Deposition	65	46	19
Dry Aerosol Deposition	150	110	44
Gas Absorption from the Atmosphere	3,040	1,950	1,090
Urban Runoff	7,130	2,100	5,030
Point Sources	47,000	4	47,000
Tributaries to Bay	120	150	95
<b><i>TOTAL</i></b>	<b>57,510</b>	<b>4,360</b>	<b>53,300</b>

Units: kg/yr.

Table 9.8. Losses of Phenanthrene from the Mainstem Chesapeake Bay.

Export to the Ocean	750
Degradation ( $k=0.045 \text{ day}^{-1}$ )	2,860
Burial in Sediments	700
<b><i>TOTAL MAINSTEM LOSSES</i></b>	<b>4,310</b>

Units: kg/yr

## **SUMMARY AND CONCLUSIONS**

The mass balance analysis for total PCBs, phenanthrene, copper and mercury reveal different levels of agreement between the inputs to the mainstem Bay and the outputs. While copper and phenanthrene show good agreement between the inputs and outputs, total PCBs and mercury do not. Both total PCBs and mercury outputs from the mainstem water column are higher than the loads to the mainstem by about a factor of 5. Unfortunately, due to the lack of sufficient data it is impossible to quantify the uncertainty for these estimates and this is where future monitoring efforts should be focused. Greatest uncertainty for the sources is most likely tributary inputs to the mainstem segment of the model, while for the output of chemicals, the greatest amount of uncertainty is probably with the export to the ocean and burial in the sediments.

The comparison between the total load below the fall line and inputs to the mainstem Bay reveal a common and important feature for all chemicals. In this analysis, most of the loads are to the tributaries (i.e., Potomac, James, York Rivers) with the majority (i.e., > 90%) of these inputs for total PCBs, phenanthrene, mercury, retained in the tributaries. Copper shows the greatest export to the mainstem from the tributaries with approximately 60% of the total load exported to the mainstem. However, due to the method used for this analysis and the available data, this estimate is tentative at best.

This study suggests focusing monitoring efforts on specific sources and geographic areas that would greatly improve and expand a mass balance and provide better check and balances between inputs and outputs. This would enable better confidence in the loading estimates from the previous chapters. For example, in many tributaries point sources or urban runoff are dominant sources. The method used to calculate these sources should be updated. This is especially true for the point source data in which there is a large range in the estimates. The best method would be to determine, by flow, the dominant point sources and analyze their effluent using state of the art methods with lower detection limits. Given that this would be very costly, select point sources that represent specific industrial types (i.e., SIC) should be monitored to provide baywide typical pollutant concentrations (TPCs) for unmonitored point sources. This data could be used in conjunction with NOAA's extensive TPC database and would greatly improve the overall point source estimate to the Bay. Additionally, the water column concentrations of many chemicals are lacking throughout the Bay with respect to the data needs of this or future models. Transport of dissolved and particulate metals and organic contaminants at the tributary and ocean boundaries is largely unknown and are a major source/sink in the model for all contaminants.

In general, basic monitoring information is needed for almost all sources and sinks identified in this report. While these monitoring data will not provide information as to the effects of chemical contaminants, they do provide the needed information as to where and how much a reduction in a particular source load is needed. Until both sources and sinks are better

## ***Mass Balance***

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quantified, future input-output balances will remain uncertain and of limited quantitative use. Once accurately verified, a mass balance model could be used to answer "what if" questions such as; if specific sources are reduced, how much reduction is needed and how long will it take to lower the concentration of a specific contaminant in the water column or an organism to a given level?

For a more complete mass balance model to be useful, its development must be driven by the objectives upon which *both* managers and scientists decide. Also, there are many questions concerning the feasibility of using a mass balance approach to manage or evaluate chemical contaminants in Chesapeake Bay. For example, if a concerted effort is applied to determine the absolute inputs and outputs from significant sources and sinks, will enough specific information exist to help managers of the various sources of contaminants (i.e., point source regulators or urban planners) determine the need for potential additional regulation of these sources? Also, if additional regulatory actions are taken, will living resources that are affected by contaminants respond and show some improvement (i.e., fewer fish advisories)?

As can be seen from the simple input-output model for the mainstem Bay, the data needs for any of these tasks are enormous and would therefore be very expensive. However, it would be useful and less expensive to focus on one tributary. This would allow a testing of specific questions as to how contaminants are transported through a system and would help guide the data needs for a much larger and complex system as the Chesapeake Bay. In addition, the preliminary mass balance indicates that a majority of the contaminants, due to their particle-reactive behavior, are trapped within the tributaries of the Bay. Therefore, it is more relevant to look at the balances within specific tributaries to determine how much material is transported to the mainstem Bay.

The development of a simple mass balance would provide useful information to Bay managers. For example, current load estimations to the Bay could be evaluated and judged for accuracy by also estimating the outputs. This would help managers and scientists determine any unrecognized source(s) to the Bay. When an accurate assessment of the relative loading exists, the importance of each source can be determined, and a determination can be made of the possible measures in controlling these sources in an overall context. This information is needed to help focus clean-up efforts and the limited dollars to areas and sources that will make the biggest difference in the overall health of Chesapeake Bay.

### ***Summary Recommendations for Implementing the Mass Balance***

- ▶ Determine the spatial/temporal distribution of dissolved, particulate and volatile chemical contaminants throughout the Bay and within the tributaries.
- ▶ Obtain accurate point source loading estimates.

- ▶ Obtain recent surface and subsurface sediment concentrations of chemical contaminants.
- ▶ Determine the depositional areas and rates within the mainstem and tributaries of the Bay.
- ▶ Derive relationships between sediment variables (e.g., sediment concentrations of metal or organic, grain size, organic carbon, etc) and the diffusion to the overlying bottom waters.
- ▶ Water and chemical exchange rates at the ocean-bay interface.
- ▶ Focus research/monitoring efforts on a specific tributary to test specific hypothesis on inputs and outputs fluxes.

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Appendix A: Chemicals and default detection limits

CHEMICAL SUBSTANCES	DEFAULT LIMITS(mg/l)
1,1,1-TRICHLOROETHANE	0.0038
1,1,2,2-TETRACHLOROETHANE	0.0069
1,1,2-TRICHLOROETHANE	0.005
1,1-DICHLOROETHANE	0.0047
1,1-DICHLOROETHYLENE	0.0028
1,2,4-TRICHLOROBENZENE	0.0019
1,2-CIS-DICHLOROETHYLENE	0.001
1,2-DICHLOROBENZENE	0.0019
1,2-DICHLOROETHANE	0.0028
1,2-DICHLOROPROPANE	0.006
1,2-DIPHENYLHYDRAZINE	0.000001
1,2-TRANS-DICHLOROETHYLENE	0.0016
1,3 DICHLOROPROPENE	0.000002
1,3-DICHLOROBENZENE	0.0019
1,3-DICHLOROPROPENE	0.000002
1,4-DICHLOROBENZENE	0.0044
2,3,7,8-TETRACHLORODIBENZOFURAN	0.01
2,4,6-TRICHLOROPHENOL	0.0027
2,4-DICHLOROPHENOL	0.0027
2,4-DIMETHYLPHENOL	0.0027
2,4-DINITROPHENOL	0.042
2,4-DINITROTOLUENE	0.0057
2,6-DINITROTOLUENE	0.0019
2-CHLOROETHYLVINYLETHER	0.00013
2-CHLORONAPHTHALENE	0.0019
2-CHLOROPHENOL	0.0033
2-METHYL-4-CHLOROPHENOL	0.003
2-METHYLNAPHTHALENE	0.01
2-NITROPHENOL	0.0036
3,3'-DICHLOROBENZIDINE	0.017
3,4-BENZOFLUORANTHENE	0.0048
4,6-DINITRO-O-CRESOL	0.024
4-BROMOPHENYLPHENYLETHER	0.0019
4-CHLOROPHENYLPHENYLETHER	0.0042
4-NITROPHENOL	0.0024
ACENAPHTHENE	0.0019
ACENAPHTHYLENE	0.0035
ACETONE	1
ACROLEIN	0.0007
ACRYLONITRILE	0.0005
ALDRIN	0.0019
ALUMINUM, ACID SOLUABLE	0.02
ALUMINUM, DISSOLVED	0.02
ALUMINUM, TOTAL	0.02
ALUMINUM, TOTAL RECOVERABLE	0.02
AMMONIA+UNIONIZED AMMONIA	0.01
ANTHRACENE	0.0019
ANTIMONY, TOTAL	0.008
ARSENIC, DISSOLVED	0.0009
ARSENIC, TOTAL	0.0009
ARSENIC, TOTAL RECOVERABLE	0.0009
ASBESTOS	
BARIUM, DISSOLVED	0.001
BARIUM, TOTAL	0.001
BENZENE	0.0044
BENZIDINE	0.044
BENZO[A]ANTHRACENE	0.0078
BENZO[A]PYRENE	0.0025
BENZO[GH]PERYLENE	0.0041
BENZO[K]FLUORANTHENE	0.0025
BERYLLIUM, TOTAL	0.00002
BHC-ALPHA	0.000003
BHC-BETA	0.0042
BHC-DELTA	0.0031
BHC-GAMMA	0.000004
BIS (2-CHLOROETHYL) ETHER	0.0057
BIS (2-CHLOROISOPROPYL) ETHER	0.0057
BIS (2-ETHYLHEXYL) PHTHALATE	0.0025
BIS(2-CHLOROETHOXY) METHANE	0.0053

Appendix A: Chemicals and default detection limits

CHEMICAL SUBSTANCES	DEFAULT LIMITS(mg/l)
BORON, TOTAL	0.003
BROMODICHLOROMETHANE	0.0022
BROMOFORM	0.0047
BUTYL BENZYL PHTHALATE	0.0025
CADMIUM, DISSOLVED	0.005
CADMIUM, TOTAL	0.005
CADMIUM, TOTAL RECOVERABLE	0.001
CARBON DISULFIDE	0.01
CARBON TETRACHLORIDE	0.0028
CHLORDANE	0.000014
CHLORIDE	1
CHLORINE, FREE AVAILABLE	0.0002
CHLORINE, FREE RESIDUAL	0.0002
CHLORINE, TOTAL RESIDUAL	0.0002
CHLOROBENZENE	0.006
CHLORODIBROMOMETHANE	0.0031
CHLOROETHANE	0.00052
CHLOROFORM	0.0016
CHLORPYRIFOS	
CHROMIUM, DISSOLVED	0.004
CHROMIUM, HEXAVALENT	0.0003
CHROMIUM, HEXAVALENT DISSOLVED	0.0003
CHROMIUM, HEXAVALENT TOTAL RECOVERABLE	0.0003
CHROMIUM, TOTAL	0.004
CHROMIUM, TOTAL RECOVERABLE	0.004
CHROMIUM, TRIVALENT	0.0001
CHRYSENE	0.0025
CLAMTROL CT-1	
COBALT, TOTAL	0.002
COPPER, DISSOLVED	0.003
COPPER, TOTAL	0.003
COPPER, TOTAL RECOVERABLE	0.003
CYANIDE	0.02
CYANIDE, FREE AMENABLE TO CHLORINATION	0.02
CYANIDE, FREE NOT AMENABLE TO CHLORINATION	0.02
CYANIDE, TOTAL	0.02
CYANIDE, TOTAL RECOVERABLE	0.02
CYANIDE, WEAK ACID DISSOCIABLE	0.02
DDD	0.0028
DDE	0.0056
DDT	0.0047
DI-N-BUTYL PHTHALATE	0.0025
DI-N-OCTYLPHTHALATE	0.0025
DIBENZO(A,H)ANTHRACENE	0.0025
DICHLOROBROMOMETHANE	0.0022
DICHLOROETHENE	0.0028
DIELDRIN	0.0025
DIETHYL PHTHALATE	0.0019
DIMETHYL PHTHALATE	0.0016
DIOXIN	0.000002
ENDOSULFAN - ALPHA	
ENDOSULFAN - BETA	
ENDOSULFAN SULFATE	0.0056
ENDRIN	0.000006
ENDRIN ALDEHYDE	0.000023
ETHION	0.0001
ETHYL BENZENE	0.0072
ETHYLBENZENE	0.0072
FLUORANTHENE	0.0022
FLUORENE	0.0019
FLUORIDE	0.1
FLUORIDE, TOTAL	
HALOGENATED HYDROCARBONS	0.0019
HEPTACHLOR	0.0022
HEPTACHLOR EPOXIDE	0.0019
HEXACHLOROBENZENE	0.0009
HEXACHLOROBUTADIENE	0.0004
HEXACHLOROCYCLOPENTADIENE	0.0016
HEXACHLOROETHANE	0.02

Appendix A: Chemicals and default detection limits

CHEMICAL SUBSTANCES	DEFAULT LIMITS(mg/l)
HEXAMETHYLPHOSPHORAMINE	0.005
HYDRAZINE	0.0037
INDENO(1,2,3-CD)PYRENE	0.03
IRON, DISSOLVED	0.03
IRON, TOTAL	0.03
IRON, TOTAL RECOVERABLE	0.0022
ISOPHORONE	0.01
LEAD, DISSOLVED	0.01
LEAD, TOTAL	0.01
LEAD, TOTAL RECOVERABLE	0.02
MAGNESIUM, TOTAL	0.001
MANGANESE, DISSOLVED	0.001
MANGANESE, TOTAL	0.007
MERCURY, DISSOLVED	0.007
MERCURY, TOTAL	0.007
MERCURY, TOTAL RECOVERABLE	
METALS, TOTAL	0.0012
METHYL BROMIDE	0.00008
METHYL CHLORIDE	1
METHYL ISOBUTYL KETONE	0.0028
METHYLENE CHLORIDE	0.02
MOLYBDENUM, TOTAL	0.00046
N-NITROSODI-N-PROPYLAMINE	0.00015
N-NITROSODIMETHYLAMINE	0.0019
N-NITROSODIPHENYLAMINE	0.0016
NAPHTHALENE	0.005
NICKEL, DISSOLVED	0.005
NICKEL, TOTAL	0.005
NICKEL, TOTAL RECOVERABLE	0.01
NITRITE PLUS NITRATE	0.0019
NITROBENZENE	0.01
NITROGEN, AMMONIA TOTAL	0.03
NITROGEN, KJELDAHL TOTAL	0.002
NITROGEN, NITRATE DISSOLVED	0.002
NITROGEN, NITRATE TOTAL	0.01
NITROGEN, NITRITE TOTAL	0.03
NITROGEN, ORGANIC TOTAL	0.03
NITROGEN, TOTAL	
NITROGLYCERIN	0.03
PCB 1221	0.001
PCB 1232	
PCB 1242	0.001
PCB 1254	0.001
PCB-1016	0.0001
PCB-1248	0.0001
PCB-1260	
PENTACHLOROBIPHENYL	0.0036
PENTACHLOROPHENOL	1
PETROLEUM HYDROCARBONS	
PETROLEUM OIL, TOTAL RECOVERABLE	0.0054
PHENANTHRENE	0.0015
PHENOL	
PHENOLICS	0.002
PHENOLS	0.01
PHOSPHATE, ORTHO	0.06
PHOSPHOROUS	0.01
PHOSPHORUS, DISSOLVED	0.01
PHOSPHORUS, TOTAL	
PHTHALATE ESTERS	0.00001
POLYCHLORINATED BIPHENYLS (PCBS)	0.0019
PYRENE	0.0006
SELENIUM, DISSOLVED	0.0006
SELENIUM, TOTAL	0.0006
SELENIUM, TOTAL RECOVERABLE	0.002
SILVER	0.002
SILVER, DISSOLVED	0.002
SILVER, TOTAL	0.002
SILVER, TOTAL RECOVERABLE	1
SULFATE	1

Appendix A: Chemicals and default detection limits

CHEMICAL SUBSTANCES	DEFAULT LIMITS(mg/l)
SULFATE, TOTAL	1
SULFIDE, TOTAL	1
SULFITE	
TANTALUM, TOTAL	0.0041
TETRACHLOROETHYLENE	0.02
THALLIUM, TOTAL	0.007
TIN, DISSOLVED	0.007
TIN, TOTAL	0.05
TITANIUM, TOTAL	0.006
TOLUENE	
TOTAL TOXIC ORGANICS	1
TOXAPHENE	0.00024
TRANS-1,2-DICHLOROETHYLENE	0.0016
TRICHLOROETHENE	0.0019
TRICHLOROETHYLENE	0.0019
TRICHLOROFLUOROMETHANE	0.01
TUNGSTEN, TOTAL	
VANADIUM, TOTAL	0.003
VINYL CHLORIDE	0.00018
VOLATILE ORGANICS	1
XYLENE	0.005
ZINC, DISSOLVED	0.002
ZINC, TOTAL	0.002
ZINC, TOTAL RECOVERABLE	0.002

Note: No data available for empty spaces under "Default Limits."

Appendix B: Loads of Chemical Categories by SIC Code

SIC CODE	SIC CODE DESCRIPTION	# OF FACILITIES UNDER SIC		INORGANICS		METALS		ORGANICS	
		AFL	BFL	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)
2011	MEAT PACKING PLANTS	1	1	62,636.18	62,636.18	905.27	913.79	0.00	102.45
2015	POULTRY SLAUGHTERING & PROCESS	1		62,093.43	62,093.43				
2021	CREAMERY BUTTER		1	295,114.09	295,114.09				
2023	CONDENSED AND EVAPORATED MILK	1		1,920.94	1,920.94				
2041	FLOUR & OTHER GRAIN MILL PROD	1		55,581.24	55,581.24				
2066	CHOCOLATE AND COCOA PRODUCTS		1	44,769.73	44,769.73	53,976.12	56,378.76		
2221	BROAD WOVEN FABRIC MILLS, SYNT	1				28.57	28.57		
2231	BROAD WOVEN FABRIC MILLS, WOOL	1				2.54	6.52		
2269	FINISHERS OF TEXTILES, NEC	1		29,863.52	29,863.52	677.11	711.38		
2491	WOOD PRESERVING	1				108.03	108.03		
2611	PULP MILLS	2		46,607.79	46,607.79	10,961.14	11,331.57	0.00	709.51
2621	PAPER MILLS	3	2	1,275,525.08	1,278,855.56	69,369.71	72,501.93	0.07	2,707.11
2631	PAPERBOARD MILLS	2		134,858.09	156,755.67	209,841.25	248,678.59	467.39	7,088.55
2676	SANITARY PAPER PRODUCTS	1		432,937.71	432,937.71				
2678	STATIONERY, TABLETS & REL PROD	1		40,920.99	40,920.99				
2816	INORGANIC PIGMENTS		2	25,362.37	25,362.37	606,833.94	619,394.74		
2819	INDUSTRIAL INORGANIC CHEMICALS		3	705,825.29	705,825.29	54,226.27	54,554.04	106.41	106.41
2821	PLSTC MAT./SYN RESINS/NV ELAST	1	1	92,061.85	92,061.85	9,474.48	13,085.67	302.74	31,524.13
2833	MEDICINAL CHEM/BOTANICAL PRODU	1		270,622.02	270,622.02	580,999.60	582,485.59		
2834	PHARMACEUTICAL PREPARATIONS	1				22.58	25.47		
2841	SOAP/DETERG EXC SPECIAL CLEANR		1	0.00	3.65	247.30	258.96	0.00	18.31
2869	INDUST. ORGANIC CHEMICALS NEC		1			1.16	1.16		
2873	NITROGEN FERTILIZERS		1	158,497,740.17	158,497,740.17	5,350.91	6,475.64	943.03	943.03
2899	CHEMICALS & CHEM PREP, NEC		1			123.28	123.40		
2911	PETROLEUM REFINING		1			1,531.63	1,605.62	0.00	278.84
2952	ASPHALT FELT AND COATINGS	1		79.03	79.03				
3111	LEATHER TANNING AND FINISHING	2		70,894.43	70,962.91	2,648.76	3,000.31	0.00	72.36
3131	BOOT & SHOE CUT STOCK & FINDNG	1		37,298.15	37,298.15	8.25	15.24		
3253	CERAMIC WALL AND FLOOR TILE	1				0.96	2.12		
3312	BLAST FURN/STEEL WORKS/ROLLING	2	2	1,798,850.37	1,798,850.37	16,585.69	20,097.20		
3322	MALLEABLE IRON FOUNDRIES	1		453.63	453.63	867.11	867.11		
3331	PRIMRY SMELTING & COPPER REFIN		1	306.03	310.86	200.57	205.20	0.00	0.35
3334	PRIMARY PRODUCTION OF ALUMINUM	1				2,846.01	3,085.21		
3351	ROLL/DRAW/EXTRUDING OF COPPER	1				526.81	534.77		
3399	PRIMARY METAL PRODUCTS, NEC	1		265,689.92	265,693.27	2,650.05	2,658.02		
3443	FAB PLATE WORK (BOILER SHOPS)	1		207,059.54	207,059.54	634.08	929.44	0.00	18.29

Appendix B: Loads of Chemical Categories by SIC Code

SIC CODE	SIC CODE DESCRIPTION	# OF FACILITIES UNDER SIC		INORGANICS		METALS		ORGANICS	
		AFL	BFL	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)
3469	METAL STAMPINGS, NEC	1				2,105.77	2,179.98		
3471	PLATING AND POLISHING	2				476.77	476.77		
3483	AMMUNIT., EXC. FOR SMALL ARMS		2	204,425.81	204,425.81	229,099.06	229,917.98	18,765.27	43,737.55
3671	ELECTRON TUBES	1				548.87	557.53		
3713	TRUCK & BUS BODIES	1				33.43	33.43		
3731	SHIP BUILDING AND REPAIRING		1	106.26	106.26	12,799.48	12,806.48		
4513	AIR COURIER SERVICES		1					70.20	127.64
4911	ELECTRICAL SERVICES	8	12	83,409.67	142,757.40	526,131.08	535,863.29	322,494.60	2,716,910.22
4931	ELEC & OTHER SERVICES COMBINED		1	33,098.13	48,755.90	2,303.92	2,646.17	0.00	2,504.67
4941	WATER SUPPLY	2				72,518.12	72,522.33	0.00	13.79
4952	SEWERAGE SYSTEMS	90	44	69,569,562.49	69,585,466.37	1,159,406.07	1,305,645.89	23,992.89	915,444.20
5171	PETROLEUM BULK STATIONS & TERM	2		63.46	63.46	2,357.50	2,364.44	2,400.92	2,428.95
8062	GEN. MEDICAL/SURGICAL HOSPITAL	1		7.13	7.13	5.13	12.64	0.00	0.41
8733	NONCOMMERCIAL RESEARCH ORGANI	1		498,557.14	498,557.14				
9199	GENERAL GOVERNMENT, NEC	1				32.36	42.86		
9511	AIR & WATER RES & SOL WSTE MGT		1			3,270.60	3,323.75		
9711	NATIONAL SECURITY		4	40,269.40	41,764.94	255,367.15	256,814.71		

Note: Empty spaces mean no data available for facilities under the SIC code by given chemical categories. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.

Appendix B.: Loads of Chemical Categories by SIC Code

SIC CODE	SIC CODE DESCRIPTION	# OF FACILITIES UNDER SIC		PAHs		PCBs		PESTICIDES	
		AFL	BFL	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)
2011	MEAT PACKING PLANTS	1	1	0.00	189.13	0.00	189.13	0.00	97.72
2015	POULTRY SLAUGHTERING & PROCESS	1							
2021	CREAMERY BUTTER		1						
2023	CONDENSED AND EVAPORATED MILK	1							
2041	FLOUR & OTHER GRAIN MILL PROD	1							
2066	CHOCOLATE AND COCOA PRODUCTS		1						
2221	BROAD WOVEN FABRIC MILLS, SYNT	1							
2231	BROAD WOVEN FABRIC MILLS, WOOL	1							
2269	FINISHERS OF TEXTILES, NEC	1							
2491	WOOD PRESERVING	1							
2611	PULP MILLS	2		0.00	446.02	0.00	16.99	0.00	62.31
2621	PAPER MILLS	3	2	0.00	3,394.91	0.00	213.27	0.00	131.91
2631	PAPERBOARD MILLS	2		33.50	6,645.50	0.00	29,972.98	0.00	11,722.20
2676	SANITARY PAPER PRODUCTS	1							
2678	STATIONERY, TABLETS & REL PROD	1							
2816	INORGANIC PIGMENTS		2						
2819	INDUSTRIAL INORGANIC CHEMICALS		3	31.80	31.80				
2821	PLSTC MAT./SYN RESINS/NV ELAST	1	1	348.93	35,431.68	0.00	273,026.07	0.00	165,794.25
2833	MEDICINAL CHEM/BOTANICAL PRODU	1							
2834	PHARMACEUTICAL PREPARATIONS	1							
2841	SOAP/DETERG EXC SPECIAL CLEANR		1	0.00	13.89				
2869	INDUST. ORGANIC CHEMICALS NEC		1						
2873	NITROGEN FERTILIZERS		1						
2899	CHEMICALS & CHEM PREP, NEC		1						
2911	PETROLEUM REFINING		1	0.00	154.17	0.00	6.68	0.00	24.49
2952	ASPHALT FELT AND COATINGS	1							
3111	LEATHER TANNING AND FINISHING	2		0.00	157.88	0.00	15.79	0.00	11.68
3131	BOOT & SHOE CUT STOCK & FINDNG	1							
3253	CERAMIC WALL AND FLOOR TILE	1							
3312	BLAST FURN/STEEL WORKS/ROLLING	2	2	100.95	774.08				
3322	MALLEABLE IRON FOUNDRIES	1							
3331	PRIMRY SMELTING & COPPER REFIN		1	0.00	0.41				
3334	PRIMARY PRODUCTION OF ALUMINUM	1		0.10	0.21				
3351	ROLL/DRAW/EXTRUDING OF COPPER	1				0.00	0.00		
3399	PRIMARY METAL PRODUCTS, NEC	1							
3443	FAB PLATE WORK (BOILER SHOPS)	1		0.00	14.14	0.00	1.64	0.00	0.42

Appendix B.: Loads of Chemical Categories by SIC Code

SIC CODE	SIC CODE DESCRIPTION	# OF FACILITIES UNDER SIC		PAHs		PCBs		PESTICIDES	
		AFL	BFL	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)	LOW LOAD (lbs/year)	HIGH LOAD (lbs/year)
3469	METAL STAMPINGS, NEC	1							
3471	PLATING AND POLISHING	2							
3483	AMMUNIT., EXC. FOR SMALL ARMS		2	0.00	179.89				
3671	ELECTRON TUBES	1							
3713	TRUCK & BUS BODIES	1							
3731	SHIP BUILDING AND REPAIRING		1						
4513	AIR COURIER SERVICES		1						
4911	ELECTRICAL SERVICES	8	12	0.00	1,997,831.60	0.00	11,571,705.14	0.00	9,843,155.17
4931	ELEC & OTHER SERVICES COMBINED		1	0.00	2,278.08				
4941	WATER SUPPLY	2		0.00	41.38	0.00	4.26	0.00	1.48
4952	SEWERAGE SYSTEMS	90	44	8,596.50	94,847.04	0.00	227,764.36	3,418.56	143,251.72
5171	PETROLEUM BULK STATIONS & TERM	2		1.01	1.02				
8062	GEN. MEDICAL/SURGICAL HOSPITAL	1		0.00	0.55	0.15	0.47	0.00	0.06
8733	NONCOMMERCIAL RESEARCH ORGANI	1							
9199	GENERAL GOVERNMENT, NEC	1		0.01	2.14				
9511	AIR & WATER RES & SOL WSTE MGT		1						
9711	NATIONAL SECURITY		4						

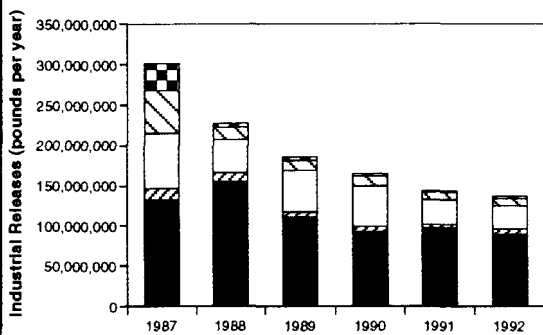
Note: Empty spaces mean no data available for facilities under the SIC code by given chemical categories. Zeros present in the loading estimates can have several meanings. A zero may indicate the chemical was non-detect, or that the flow was reported as zero for a given record, or that the concentration was reported as zero for a given record, or that the concentration value was not recorded in the PCS database.



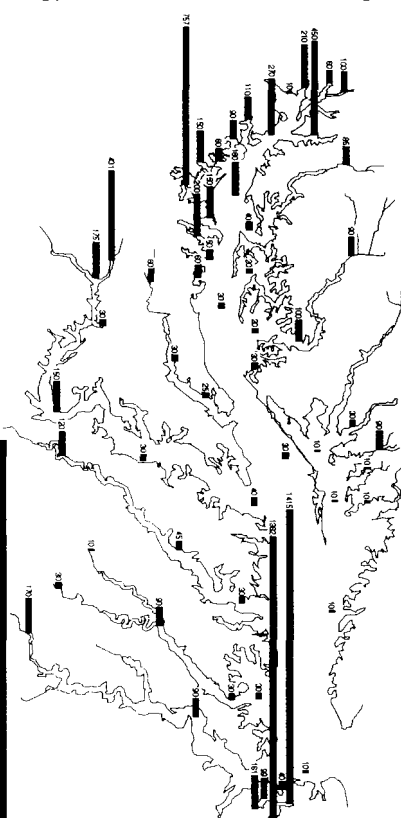
# CHESAPEAKE BAY BASINWIDE TOXICS REDUCTION STRATEGY REEVALUATION REPORT

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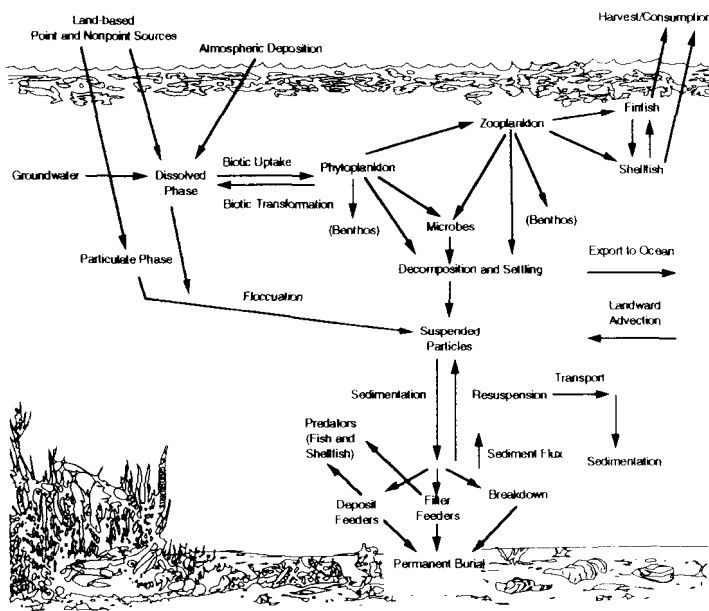
Chesapeake Bay Basin Industrial Releases of Chemicals



Benzo[a]pyrene Concentrations in Chesapeake Bay



Sources, Transport, Fate, and Effects of the Chemical Contaminants in Chesapeake Bay



Chesapeake Bay Program



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# **CHESAPEAKE BAY BASINWIDE TOXICS REDUCTION STRATEGY REEVALUATION REPORT**



Report from the  
Chesapeake Bay Program's  
Toxics Subcommittee

to the

Implementation Committee,  
Principals' Staff Committee,  
and the  
Chesapeake Executive Council

Annapolis, Maryland  
September 1994

CBP/TRS 117/94

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## EXECUTIVE SUMMARY

The 1987 Chesapeake Bay Agreement committed the signatories to “develop, adopt and begin implementation of a basinwide strategy to achieve a reduction of toxics, consistent with the Clean Water Act of 1987, which will ensure protection of human health and living resources.” The resultant *Chesapeake Bay Basinwide Toxics Reduction Strategy*, adopted by the Chesapeake Executive Council in January 1989, initiated a multi-jurisdictional effort to define the nature, extent, and magnitude of Chesapeake Bay toxics problems more accurately and initiate specific toxics reduction and prevention actions. The Chesapeake Bay Agreement signatories also committed to reevaluate the strategy during 1992. The objectives of this strategy reevaluation were to define:

- what we now know about the nature, extent, and magnitude of Bay toxics problems;
- what steps should be taken to reduce and prevent impacts from chemical contaminants; and
- what information is still needed to determine future actions.

The Chesapeake Bay Program’s Toxics Subcommittee investigated and evaluated the complex nature of the Bay’s toxics problems through a two-year schedule of meetings, research workshops, and information-gathering forums. Key to building a technical consensus on the nature and extent of the Bay’s toxics problems was a series of seven critical issue forums: wildlife contamination, pesticides, groundwater loadings, atmospheric deposition, sediment contamination, finfish/shellfish tissue contamination, and water column contamination. Regional and national technical experts were invited to work with the Toxics Subcommittee in these one-day forums to analyze available data and information and assess their usefulness in determining the adverse impacts to the Bay from potentially toxic chemicals.

The strategy reevaluation found no evidence of severe chemical contamination impacts that are baywide like other problems, such as excess nutrients which has caused declines in underwater grasses and low dissolved oxygen levels. The reevaluation did, however, clearly document severe localized toxicity problems, adverse effects from chemical contamination on aquatic organisms in areas previously considered unaffected, and widespread low levels of chemical contaminants in all Bay habitats sampled.

Existing state and federal regulatory and management programs continue to reduce the input of potentially toxic chemicals to the Chesapeake Bay. Measured concentrations of many of these chemical contaminants in the Bay’s bottom sediments, fish, shellfish, and wildlife have also generally declined although elevated levels occur in several industrialized areas and some increasing trends have been observed. Progress in reducing the point sources of these chemical contaminants is offset by significant nonpoint source inputs of chemical contaminants (e.g., urban stormwater runoff, atmospheric deposition) from increasing development and urbanization of the Bay watershed.

This report not only documents the findings of the two-year information gathering process of the strategy reevaluation but also recommends an approach for undertaking future toxics reduction and prevention actions in the Bay watershed. The recommended approach, derived from the 1989 *Chesapeake Bay Basinwide Toxics Reduction Strategy*, targets toxics reduction and prevention actions in four ways by:

- recognizing pollution prevention as the preferred means of reducing risks to human health and living resources due to exposure to potentially toxic chemicals;
- ensuring actions taken are both consistent with and supplement the requirements of the Clean Water Act and Clean Air Act;
- directing reduction and prevention actions towards regions with known toxic problems as well as areas where significant potential exists for toxic impacts on the living resources and habitats; and
- ensuring toxics assessments will directly support management decisions for reduction and prevention actions.

## Sources of Chemical Contaminants

Estimated chemical contaminant loadings and releases in the initial *Chesapeake Bay Basinwide Toxics Loading and Release Inventory* are based on limited available data from a variety of sources covering different time periods. As a result, the estimates provide only for order of magnitude comparisons between sources. The reported loadings are only for those chemical contaminants identified as Chesapeake Bay Toxics of Concern—chemical contaminants either adversely impacting the Bay system or for which the reasonable potential to do so exists.

### Metals

The highest estimated Toxics of Concern metal loadings to the Bay basin come from urban stormwater runoff, followed by point sources and atmospheric deposition; all these loadings were within the same order of magnitude (Table I). Point sources are a significant source of metal loadings only to the tidal reaches of the upper western shore tributaries and in the Susquehanna, Potomac, and James basins. Atmospheric deposition direct to tidal surface waters is a secondary, yet significant, source of metal loadings to the entire mainstem Bay and tidal tributaries due to its widespread distribution. Estimated loadings of metals from shoreline erosion are the same order of magnitude as atmospheric deposition loadings to tidal waters. Across all inventoried sources (except for fall line loadings), the Potomac basin has the highest metals loading followed by the Susquehanna, West Chesapeake, James, mainstem Bay, Patuxent, Eastern Shore, York, and Rappahannock basins.

Estimated fall line loadings of metals for the Susquehanna, Potomac, and James rivers are an order of magnitude higher than the combined metal loadings from above fall line point sources and above fall line urban stormwater runoff, indicating an underestimation of loadings to surface waters above the fall line. Fall line loadings are generally measured at the point in the river where the nontidal watershed meets the tidally influenced watershed.

Groundwater loadings of metals to Bay tidal waters are currently unknown, but are likely to be more significant close to the original source of contamination. Estimated loadings of metals from commercial shipping and transport activities and pesticide applications (e.g., copper) were not significant compared with the above described sources at the basinwide scale. Contributions to total metal loadings to Bay tidal waters that are currently unknown include: bulkheads, piers, and pilings built with wood that is pressure treated with chromated copper arsenate, runoff from marina facilities, and leachates from antifoulant boat bottom paints. Loadings from all these sources may be significant at the local scale.

**Table I.** Basinwide comparisons of Toxics of Concern/Secondary List metal, organic compound, and pesticide loadings by source category.

Class of Toxic Substances	Point Sources		Urban Stormwater Runoff		Atmos. Dep. <sup>3</sup>	Shipping and Transport	Fall Line
	AFL <sup>1</sup>	BFL <sup>2</sup>	AFL	BFL			
Metals	○	●	●	●	○	—	●
Organics	—	●	●	●	●	○	●
Pesticides	○	—	—	—	●	—	●

Key:

	<u>Metals</u>	<u>Organics</u>	<u>Pesticides</u>
● = High range of loadings/releases:	>1,000,000	>2,000	>5,000
● = Medium range of estimated loadings/releases:	500,000-1,000,000	1,000-2,000	1,000-5,000
○ = Low range of estimated loadings/releases:	1-500,000	1-1,000	1-1,000
— = No estimated loading/release.			

Notes:

1. Above fall line.
2. Below fall line.
3. Atmospheric deposition to Chesapeake Bay tidal surface waters only.

## Organic Chemicals

The highest estimated loadings of Toxics of Concern organic chemical contaminants (polycyclic aromatic hydrocarbons and polychlorinated biphenyls) to the Bay basin are from atmospheric deposition, followed by urban stormwater runoff, and point sources (Table I). All these loadings were within the same order of magnitude. Shipping is a relatively minor source of these organic chemical contaminants. Across all inventoried sources (except fall line loadings), the West Chesapeake has the highest organic chemical compound loadings followed by the mainstem Bay, Susquehanna, Potomac, James, Eastern Shore, Patuxent, York, and Rappahannock basins.

Estimated fall line loadings from the non-tidal reaches of the Bay's three major basins—the Susquehanna, Potomac, and James—were a very minor source of organic chemical contaminants to Bay tidal waters compared to other inventoried sources. These minor loads indicate that inventoried loads to non-tidal tributaries are diminished by chemical and physical degradation en route to the fall line.

## Pesticides

Estimates of pesticide loadings could be made for only two inventoried sources from the available data. Loadings direct to tidal waters from atmospheric deposition were an order of magnitude higher than combined fall line loadings for the Susquehanna, Potomac, and James rivers (Table I). The atmospheric deposition loadings may be an overestimate and the fall line loading does not account

for the remaining 20 percent of the freshwater flow into the Bay from other Bay tributaries. Atmospheric deposition, however, results in the widespread distribution of pesticide loadings across all tidal waters whereas fall line loadings contribute only to tidal areas immediately downstream of the fall line.

The highest total pesticide applications were reported for the Potomac basin (which includes 22 percent of the watershed land area), followed by the Eastern Shore (7.5 percent), Susquehanna (42 percent), James (16 percent), West Chesapeake (2 percent), Rappahannock (5 percent), York (4 percent), and Patuxent (1.5 percent) basins. Herbicides accounted for 70 percent of the total usage of pesticides reported basinwide followed by insecticides (20 percent) and fungicides (10 percent). In the Susquehanna, Potomac, and James basins, the estimated fall line loadings of pesticides were less than one tenth of a percent of the estimated total annual pesticides applied in the upland, non-tidal watershed.

Although pesticides have been detected in shallow aquifers, surface runoff is a larger source of pesticides to streams and tributaries than groundwater. Any potential for groundwater to be a significant loading source of pesticides is greatest at the local scale—close to the original source of contamination.

## **Chemical Contaminants in Bay Habitats**

In their 1987 review of Chesapeake Bay contaminant issues, scientists from the University of Maryland and the Virginia Institute of Marine Science stated “No matter where we look in the Bay, we find evidence of some chemical contamination... Many of the contaminants found in highly impacted areas are also now found in remote areas, but at much lower concentrations. There are probably no pristine, truly uncontaminated sites left in Chesapeake Bay.” The authors conclude that “In highly impacted areas, such as the Elizabeth River and Baltimore Harbor, evidence of adverse impacts upon aquatic organisms and reduced biological diversity exists. It is likely that toxic materials are responsible for these effects. However, pervasive low level contamination occurring in the mainstem of the Bay has not been equivocally linked to any biological deterioration.”

The major findings from more recent efforts to better define the nature, magnitude, and extent of Chesapeake Bay toxic problems are summarized below. These findings support the conclusions of the 1987 review article. In the seven years since the article’s publication, we have gained a better understanding of chemical contaminant loadings and releases and have documented evidence for the adverse effects of chemical contaminants in Bay habitats beyond areas with known toxics problems. We now have an expanded base of knowledge and understanding on which to target ongoing and future toxics reduction and prevention programs and can direct future assessments toward determining whether low levels of potentially toxic chemicals are causing adverse biological effects in Bay habitats.

### **Water Column Concentrations**

Because of the high concentrations observed, the surface microlayer may be an important site for the transfer of chemical contaminants to both the water column and the Bay’s living resources. Only limited data and evidence exist to determine direct biological effects to organisms coming in contact with the surface microlayer.



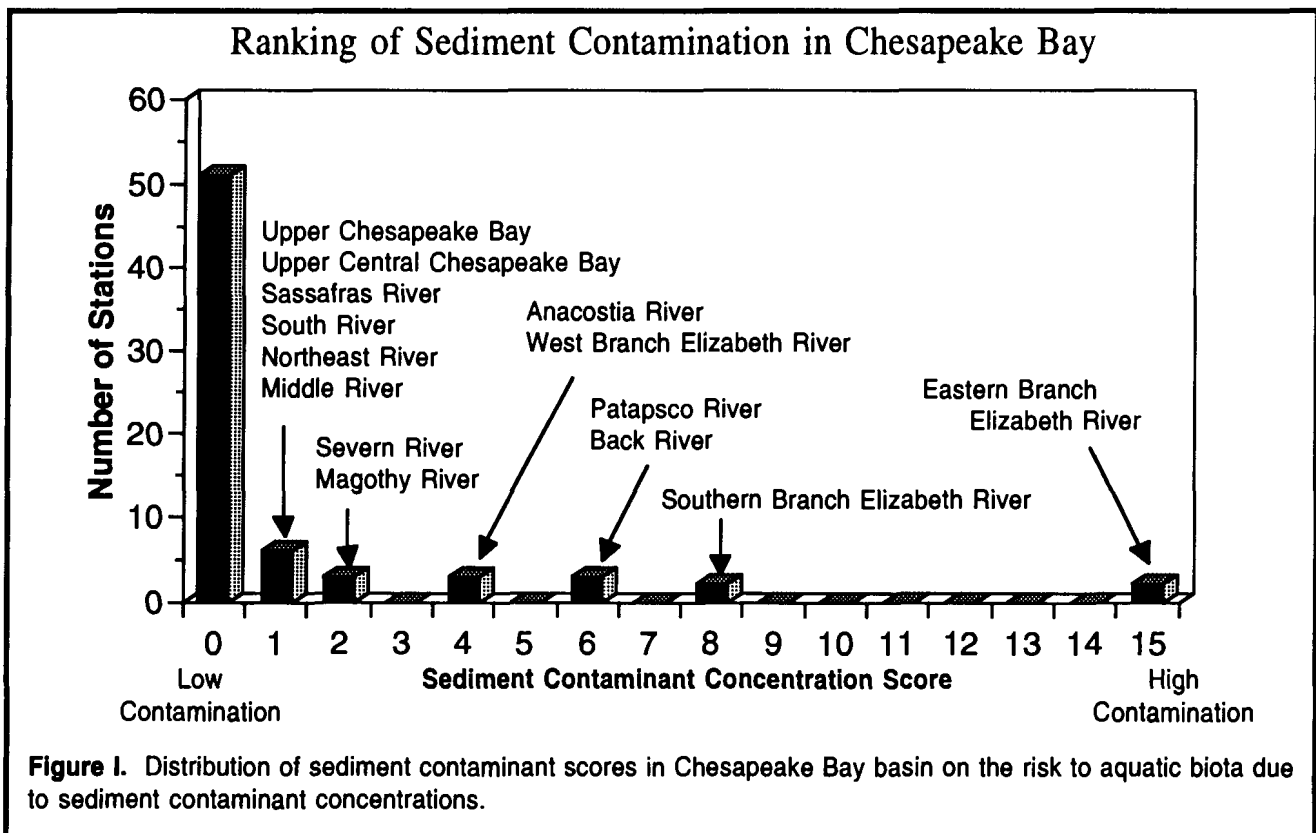
No widespread occurrences of measured metal concentrations exceeding EPA water quality criteria or state water quality standards exist in the mainstem Bay. Most Bay tributary water column metal concentration data collected over the past two decades were reported as below analytical detection limits. Measured concentrations of metals were higher in some non-tidal and tidal tributaries compared to the mainstem Bay, with a very limited number exceeding EPA water quality criteria and/or state water quality standards. As most of the metals data were reported as total recoverable concentrations it is difficult to assess potential risks to living resources since EPA criteria and state standards focus on the dissolved fraction—that amount in the water column considered “bioavailable” to aquatic organisms.

Pesticides in the water column may pose a risk to living resources during and shortly after storms in the spring and summer when pesticides are most heavily used. The highest water column concentrations generally have been measured in non-tidal freshwater streams closest to the application site, with very few observed concentrations above EPA aquatic life criteria or drinking water standards.

Limited data for tidal and non-tidal waters throughout the Bay indicate that concentrations of organic chemical contaminants are generally below conventional analytical detection limits (i.e., below part per billion concentrations). Most organic chemical contaminants readily attach to sediment particles and become embedded in the bottom sediments or are incorporated into biota.

## Sediment Contamination

A few areas of the Bay which are heavily industrialized and/or urbanized—Baltimore Harbor, Back River, Anacostia River, and Elizabeth River—have sediment concentrations of many chemical contaminants high enough to likely affect aquatic organisms adversely (Figure I). The severe sediment

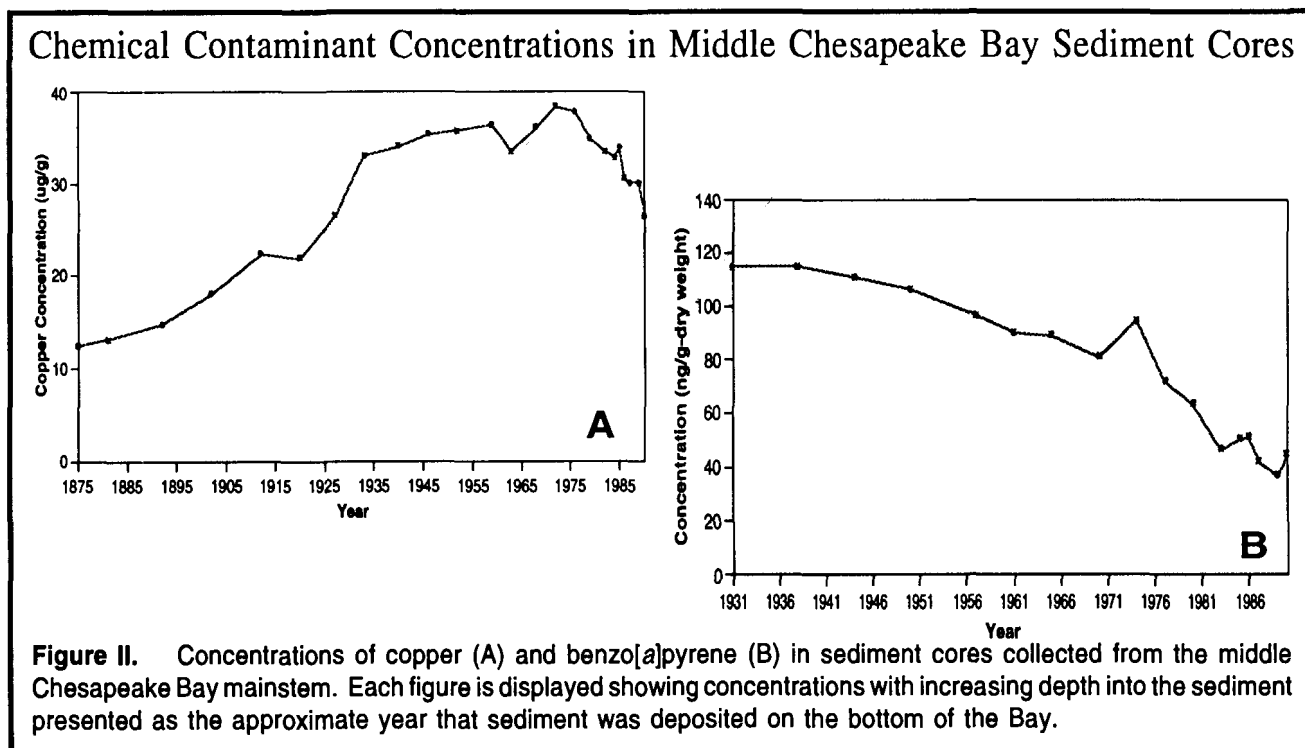


contamination in these areas is due largely to historical sources of chemical contaminants. Estimates of relative risk to aquatic organisms due to sediment contamination in these areas are much higher than those for other areas of the Bay. Other localized areas with elevated sediment contaminant concentrations have been documented around point source discharges, within marinas, or adjacent to military facilities beyond the four areas described above.

Areas in and near the heavily populated or rapidly growing areas in the northern and western shores of the Chesapeake Bay have the next highest levels of sediment contamination (Figure I). The lowest levels of sediment contamination are in the less populated, rural areas of the southern and eastern portions of the Chesapeake Bay and its tidal tributaries. Data from these less populated areas indicate that sediment contaminant concentrations are not at levels that would cause adverse effects on aquatic organisms.

In most regions, sediment concentrations of metals appear to pose greater estimated risks to aquatic organisms than do sediment concentrations of polycyclic aromatic hydrocarbons. Metal concentrations were higher than thresholds associated with probable or potential effects more often than organic chemical contaminants. These thresholds only indicate the relative probability of observing effects, not that effects will be found if the threshold is exceeded. Sediment concentrations of polychlorinated biphenyls and pesticides appear to pose an even lesser risk to aquatic organisms outside of the areas with highly contaminated sediments as most observed concentrations were well below thresholds associated with probable or potential adverse effects.

Results from past and recent sediment core analyses and comparisons of 1991 sediment contaminant concentrations with measurements from the late 1970s to the mid-1980s all point towards declining sediment concentrations for many metals, pesticides, and organic chemical contaminants (Figure II). These data reflect decreases in the historical sources of chemical contaminants to Bay sediments over the past several decades.



## Effects on Bay Resources

### Ambient Effects on Aquatic Organisms

Adverse impacts on aquatic organisms have been observed in a variety of Bay habitats (Table II). Observation of these adverse ambient effects in Bay habitats such as the Nansemond, Elk, Sassafras, and Wye rivers, generally considered to be unimpacted by chemical contaminants, raises concerns about other regions of the Bay generally not regarded as toxic problem areas. The presence of potentially toxic chemicals in these areas suggests that the combined effects of multiple chemical contaminants may be a factor in causing the observed effects—death, reduced growth and reproduction, tumors. Outside of the highly chemically contaminated areas of the Bay, however, it is not known if these adverse effects are caused by chemical contaminants or by other environmental conditions not related to chemical contamination.

**Table II.** Areas in Chesapeake Bay where ambient effects have been observed.

Upper Chesapeake Bay	Middle River	Choptank River	Rappahannock River
Susquehanna River	Back River	Potomac River	York River
Chesapeake and Delaware Canal	Patapsco River	Anacostia River	Nansemond River
Elk River	Severn River	Nanticoke River	James River
Sassafras River	Wye River	Pocomoke River	Elizabeth River

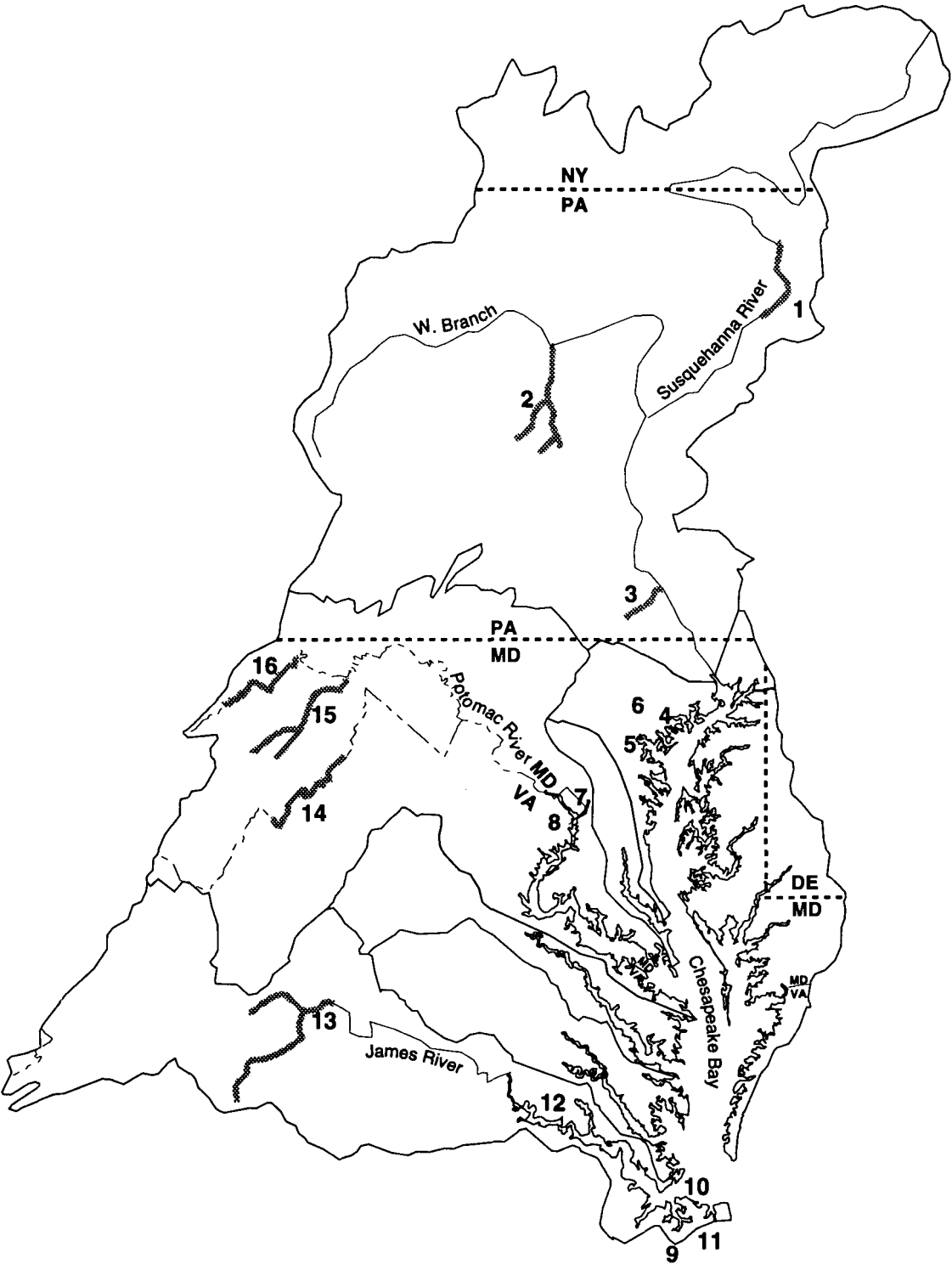
### Finfish and Shellfish Tissue Concentrations

There have been significant declines in finfish and shellfish tissue contaminant concentrations throughout the Chesapeake Bay and its tidal tributaries since the 1970s for several metals, pesticides, and organic chemical contaminants. Similar downward trends in tissue concentrations have been observed in the non-tidal portions of the Bay basin. Concentrations of a few metals, however, show recent increasing trends in concentrations.

The highest levels of shellfish and finfish contamination occurred at stations in the northern Bay and the Elizabeth River. Based on comparisons with data from areas across the country with known finfish tissue contamination problems, it appears that maximum concentrations of some chemical contaminants in Chesapeake Bay basin finfish are not as high as the maximum concentrations measured in northeast states or the Great Lakes. A few chemicals in areas with existing fish consumption restrictions in place — chlordane in Back River and PCBs in the Shenandoah River — show maximum concentrations comparable to these other areas of the country.

Within the Chesapeake Bay basin, the existing bans or advisories on finfish/shellfish consumption are focused primarily on bottom-feeding finfish contaminated with chlordane, dioxin, mercury, and/or PCBs (Figure III). Past fish consumption bans (Kepone in the James River) or restrictions (dioxin in the North Branch of the Potomac River within Maryland) have been lifted due to tissue contaminant concentrations falling below health advisory standards. Outside of these areas, the available tissue

Finfish and Shellfish Consumption Bans and Restrictions  
in the Chesapeake Bay Basin



**Figure III.** General location of the finfish and shellfish consumption bans and advisories within the Chesapeake Bay basin. The numbers refer to specific streams, lakes, and rivers listed in Table 44 of the main report.

data indicate no cause for human health concerns. A more complete assessment of Bay finfish and shellfish tissue contamination problems is not possible at this time due to areas with no tissue data, lack of action levels for a wide range of chemical contaminants, and an uncertain relationship between tissue concentrations and ecological impacts.

## Wildlife Impacts

Although organochlorine pesticides and, perhaps, PCBs affected birds throughout the Chesapeake Bay basin in the past, there is little evidence that they are still causing significant adverse impacts. Continued increasing population trends in two bird species—bald eagles and ospreys—historically impacted by these toxic chemicals indicate that the severe wildlife contamination problems once present throughout the Bay basin have diminished. Waterfowl, raptor, and wading bird contamination issues in Chesapeake Bay basin have moved from concerns of severe basinwide impacts due to elevated concentrations of a number of toxic chemicals to a much more limited set of species, single chemical contaminant, and region-specific issues. Existing data are too limited to determine whether chemical contaminants are adversely impacting Chesapeake Bay populations of mammals, reptiles, and amphibians.

## Regulatory and Management Programs

The 1989 *Basinwide Toxics Reduction Strategy* was written “to achieve a reduction of toxics consistent with the Water Quality Act of 1987” and build upon existing regulatory and management programs. Many of the environmental responses and trends described resulted directly or indirectly from implementation of these state and federal programs.

### Pennsylvania

The Pennsylvania Department of Environmental Resources regulates chemical contaminants through chemical-specific numeric and narrative water quality standards. These standards are the basis for the water quality-based effluent limitations incorporated into permits and used for other regulatory actions to protect water uses. Pennsylvania is a National Pollutant Discharge Elimination System (NPDES) delegated state, carrying out permitting, compliance, and enforcement programs in accordance with state and federal regulations. Through the implementation of the federal stormwater permitting regulations, Pennsylvania has issued stormwater permits for industrial and construction activities.

Pennsylvania controls pesticide use through programs that require licensing of all pesticide applicators and actively promotes the use of integrated pest management techniques.

Residual and hazardous waste regulations have been developed as part of Pennsylvania’s hazardous waste management program to focus on source reduction for waste prevention. In addition to playing an active role in clean up efforts at the 99 sites on the Superfund Program’s National Priority List, Pennsylvania is pursuing remediation at sites not on the national list.

Pennsylvania requires the application of best available technology to control toxic air pollutants from new sources. As part of its new regulations to implement the Clean Air Act amendments, Pennsylvania plans to incorporate pollution prevention requirements when possible.

## **Maryland**

Water quality standards in Maryland are designed to protect all waters both for recreational use and the propagation and growth of a balanced population of fish and wildlife. Maryland uses chemical-specific limits in conjunction with biological monitoring to control point source discharges of chemical contaminants. Dischargers with potentially toxic effluents have had requirements incorporated into their permits for biomonitoring. Those facilities with toxic discharges are required to conduct confirmatory testing and undergo a toxicity reduction evaluation to identify and remove the sources of toxicity within the plant or collection system. Approved programs delegating authority to issue pretreatment permits have been established in 17 jurisdictions statewide.

Maryland's pesticide management program tracks pesticides used in Maryland, ensures their safe use through applicator certification and training, and promotes the use of integrated pest management techniques.

Maryland established a Pollution Prevention/Waste Minimization program in 1990 to provide technical assistance and a clearinghouse of information on available reduction processes and technologies to over 3,000 waste generators. In addition to the national law, Maryland has enacted its own Superfund law under which it focuses remediation on sites not on the National Priority List.

Maryland toxic air pollutant regulations were promulgated in 1988 to restrict the emissions and subsequent land and water deposition of chemical contaminants. These regulations require that emissions be quantified and reported. All new sources are required to employ best available control technology and evaluate pollution prevention options.

## **District of Columbia**

The District of Columbia's point source control program focuses on the Blue Plains Wastewater Treatment Plant. Presently the EPA issues NPDES permits for the District of Columbia, with review and comments provided by the district. Under its pretreatment regulations, the District of Columbia issues discharge permits to control chemical contaminants coming from industrial discharges to the sewer system.

Through its Stormwater Management Program, established in 1984, the District of Columbia controls nonpoint source pollution by ensuring that developers control both the quantity and quality of stormwater runoff from project sites by using best management practices. Under the program, all construction and grading plans submitted to the District of Columbia government must be reviewed and approved for compliance with stormwater management regulations.

The main objective of the District of Columbia's Pesticide Management Program is to train and certify pesticide applicators in the proper labeling, distribution, disposal, storage, transportation, and safe use and handling of pesticides. The district initiated an Integrated Pest Management program in 1992 targeted towards organizations and businesses registered to apply pesticides in the District of Columbia and residential users of pesticides.

The District of Columbia's Hazardous Waste Management Program focuses on regulation development, permitting, program administration, waste minimization and pollution prevention, and compliance monitoring and enforcement. Site inspections determine whether generators, transporters,

and storage facilities are complying with applicable regulations. A revised waste minimization and pollution prevention program is being developed to meet the 1993 Capacity Assurance Plan submittal requirements. This program endorses the national goals of pollution prevention and waste reduction. The technical assistance portion of this program will identify source reduction and recycling opportunities, promote additional waste minimization methods through the distribution of fact sheets, and promote in-house waste reduction audits for specific industries.

## Virginia

Virginia's instream water quality standards are both narrative statements and numerical limits for specific chemical contaminants. Virginia has been delegated responsibility for the NPDES, federal facility, and pretreatment permitting programs. Through Virginia's Toxics Management Program, dischargers are required to conduct both biological and chemical monitoring of their effluents. If an effluent shows acute and/or chronic toxicity, the permittee is required to perform a toxicity reduction evaluation and treat the discharge to reduce the toxicity to an acceptable level. Eleven municipal sewer systems in Virginia's Chesapeake Bay drainage area are required to file stormwater permit applications under the national stormwater regulations.

Virginia's Pesticide Control Board oversees pesticide businesses, certification of pesticide applicators, and setting of fees. In 1990, Virginia initiated a program to collect and dispose of unwanted pesticides from agricultural producers. A pilot program to recycle plastic pesticide containers was implemented in three counties in 1992 and expanded to six localities in 1993.

Virginia has an extensive set of regulatory programs addressing solid waste, hazardous waste, and hazardous waste sites. These programs encompass solid, hazardous, and radioactive waste, emergency planning for hazardous waste, and hazardous waste transportation activities to protect human health and the environment.

The Air Toxics Program in the Virginia Department of Environmental Quality is charged with the maintenance and improvement of the state's air quality. Emphasis is being directed at a health-based state air toxics program and the technology-based hazardous air pollution control program requirements of the 1990 Clean Air Act Amendments. Since adoption of the 1989 *Basinwide Toxics Reduction Strategy*, activities have included permit application review, inventorying facilities to identify chemicals emitted, canister sampling for chemicals, and other atmospheric deposition monitoring.

## Progress Towards the Strategy's Goals

The 1989 basinwide strategy committed the Chesapeake Bay Agreement signatories to two goals:

"The long-term goal of this Strategy is to work towards a toxics free Bay by eliminating the discharge of toxic substances from all controllable sources," and

"By the year 2000, the input of toxic substances from all controllable sources to the Chesapeake Bay will be reduced to levels that result in no toxic or bioaccumulative impacts on the living resources that inhabit the Bay or on human health."

The strategy reevaluation revealed examples of both programmatic and environmental progress as well as areas requiring attention in the future.

## **Definition of Bay Toxics Problems**

- The Bay basin states have identified 68 facilities as dischargers of chemical contaminants in quantities that exceed water quality standards or criteria and have taken actions to reduce chemical contaminant loadings from these facilities (Figure IV).
- Virginia began implementation of the five-year Elizabeth River Toxics Initiative in 1988 with investigations of the sources of chemical contaminant loadings and ambient concentrations and expanded facility inspections.

## **Reductions in Chemical Contaminant Loadings**

- The national Toxics Release Inventory has reported significant decreases in Bay basin industrial releases of chemicals to air, land, and water since 1987 (Figure V).
- Maryland has documented substantial reductions in chemical contaminants discharged into Baltimore Harbor and the Patapsco River. The reductions were accompanied by significant improvements in the number and diversity of bottom-dwelling organisms.
- The significant decline in the lead concentrations of precipitation at an atmospheric deposition monitoring station at Lewes, Delaware since 1982 is the direct result of banning lead as a gasoline additive.
- Observations of elevated water column concentrations of pesticides just downstream from a Virginia pesticide mixing and loading facility triggered operational and structural changes at the facility, dramatically decreasing pesticide runoff.

## **Reductions in Ambient Chemical Contaminant Concentrations**

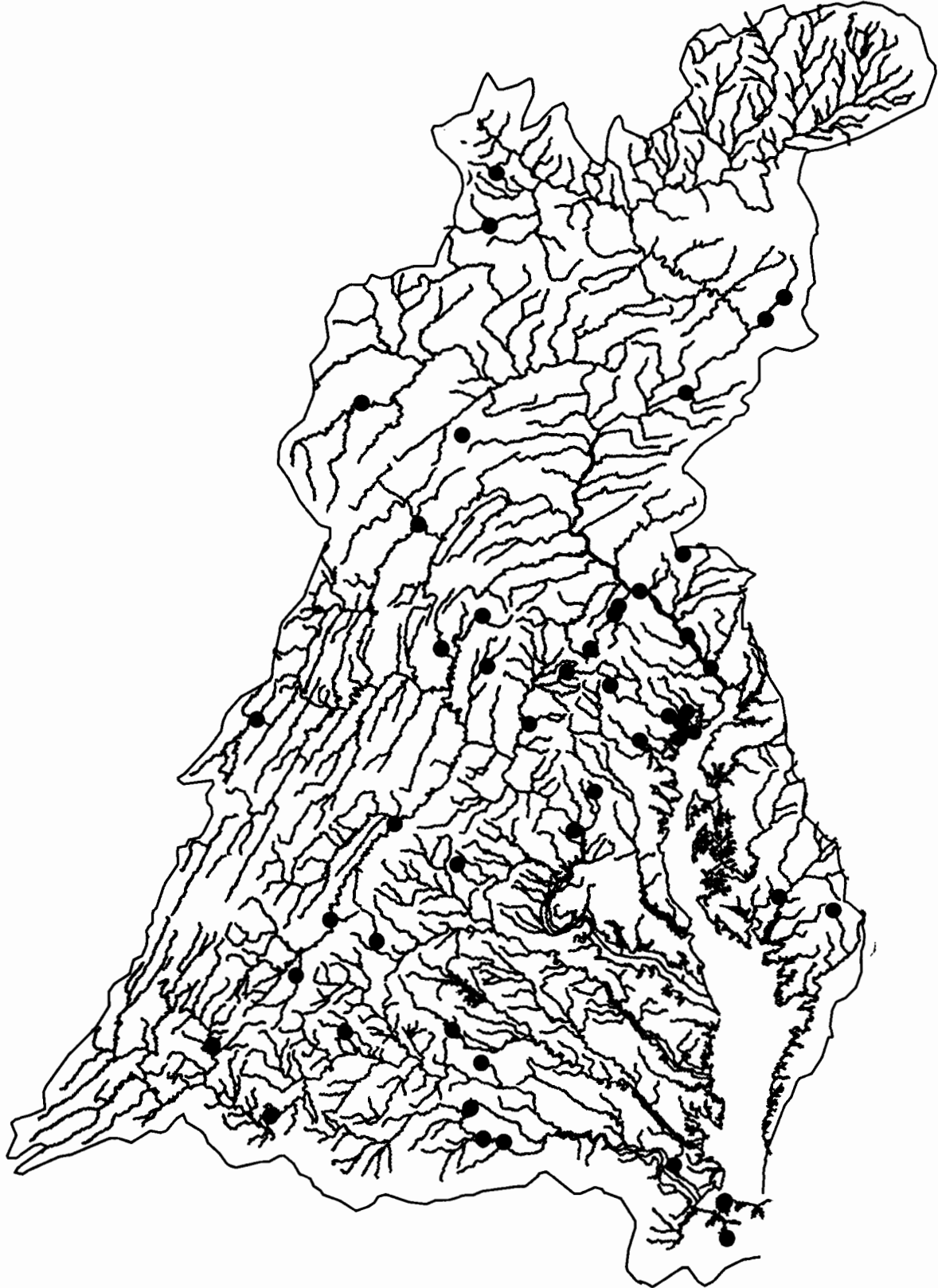
- Declines in tributyltin concentrations have been documented since restriction of its use in boat bottom antifouling paints.
- Mainstem Bay sediment concentrations of most metals and many organic chemical contaminants have declined over the past several decades.
- Maryland has documented declines in shellfish tissue concentrations of metals and pesticides since the early 1970s (Figure VI).
- Basinwide decreases in organochlorine pesticide concentrations in Bay water birds have resulted in increasing populations of bald eagles and ospreys.

## **Management of the Application of Pesticides**

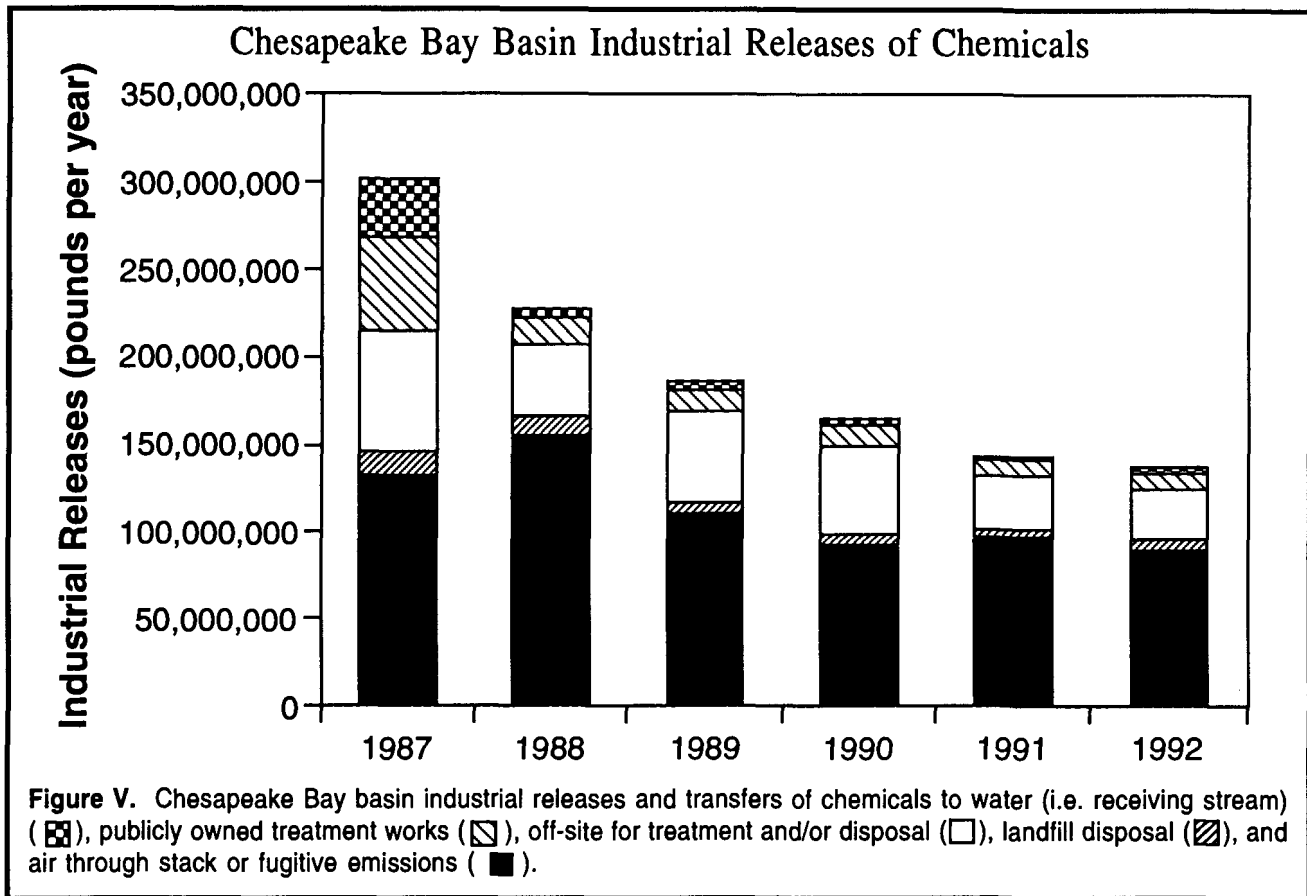
- Thousands of acres of agricultural land in the Bay watershed have been brought under a system of integrated pest management (Figure VII).
- Collections of unusable and banned pesticide products in Virginia and Pennsylvania have ensured the proper disposal of thousands of pounds of chemicals which posed a serious hazard to both farmers and the environment.



### Chesapeake Bay Basin 304(l) Facilities



**Figure IV.** Locations of the state designated 304(l) facilities (●) within the Chesapeake Bay basin.



## Minimizing Chemical Contaminant Loadings

- Counties and municipalities in Pennsylvania, Maryland, Virginia, and the District of Columbia collect a wide range of potentially hazardous household products from thousands of residents through innovative collection programs.

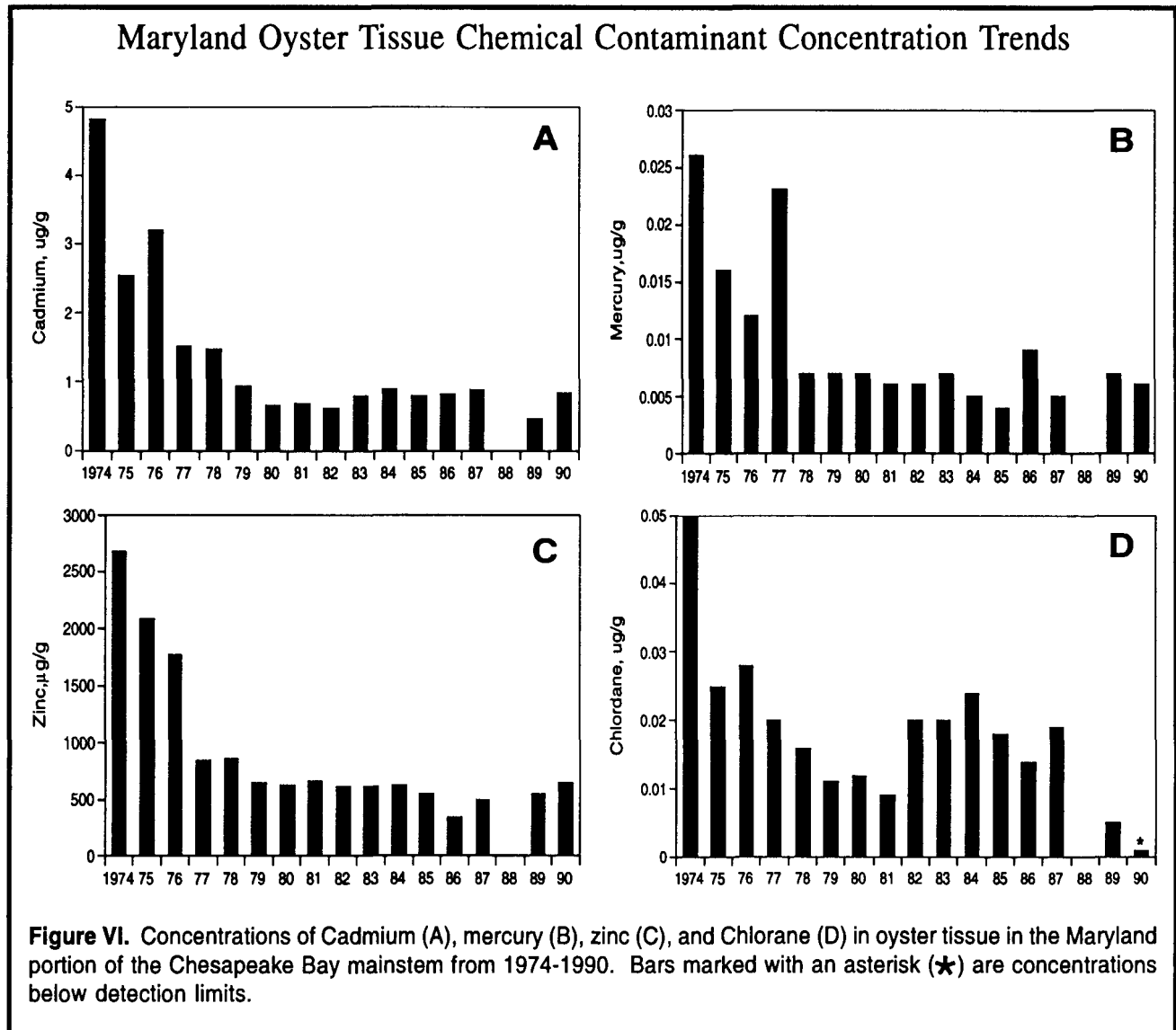
## Refinements to the Strategy

The reevaluation has shown that significant steps have been taken to control the input of chemical contaminants to the Bay system over the past decade. Much remains to be done, however, to address the known and potential toxic problems identified by the reevaluation.

Based on strategy reevaluation report findings, the Chesapeake Executive Council directed the Bay Agreement signatories to revise the existing Basinwide Toxics Reduction Strategy by the next Executive Council meeting. During its September 1993 meeting, the Executive Council directed that the revised strategy emphasize four areas: pollution prevention, regulatory program implementation, regional focus, and directed toxics assessments.

## Pollution Prevention

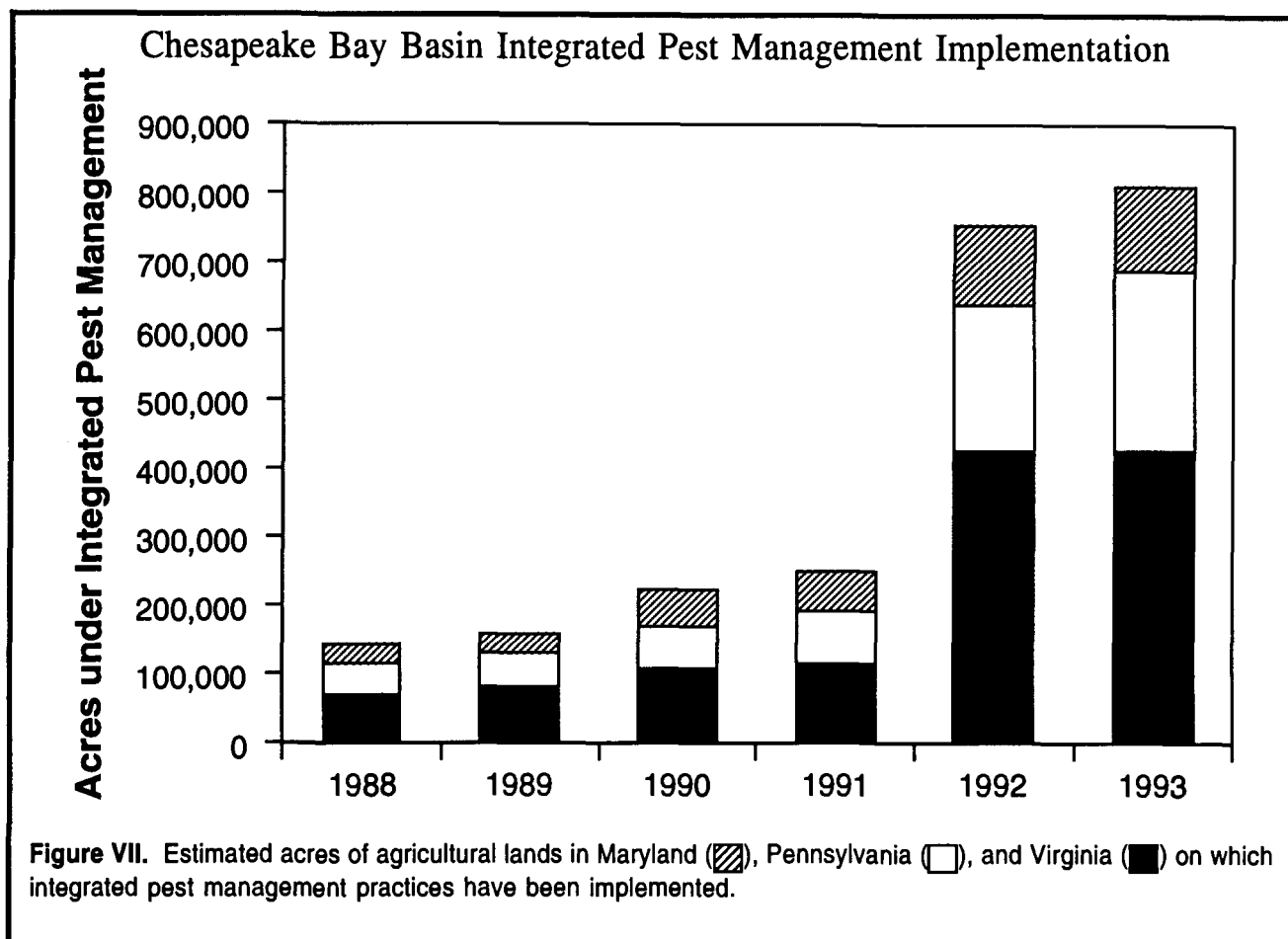
Building upon existing state and federal efforts to encourage adoption of pollution prevention approaches, findings from the reevaluation of the basinwide strategy should be used to target prevention opportunities. Geographically targeting Regions of Concern and Areas of Emphasis is one example of applying new information on the nature, magnitude, and extent of Bay toxic problems.



The revised strategy needs to take advantage of the existing and often extensive institutional structures already in place within the industrial manufacturing and commercial sectors, rather than attempting to create a new, overlapping infrastructure. Many of these existing institutional structures (e.g., statewide chambers of commerce) have members with a strong commitment to the adoption of pollution prevention approaches. A strong link between the strategy reevaluation findings and existing commitments to pollution prevention should be forged within the revised strategy.

Integrated pest management is a decision-making process that uses regular monitoring to determine if and when pesticide treatments are needed. This type of management employs physical, mechanical, cultural, biological, and educational methods to keep pest numbers low enough to prevent intolerable damage or annoyance. Chemical treatments are applied only when monitoring has indicated that the pest will cause unacceptable economic or aesthetic damage. Least toxic chemical controls are used only as a last resort.

In both the urban and agricultural settings, the greatest impediment to implementation of integrated pest management is the availability of experts beyond cooperative extension agents. An alternative



or supplemental source of expertise exists within commercial agrichemical dealerships and urban pest control services. In partnership with private interests, a two-pronged approach could be taken. Agricultural agencies could ensure that a professional crop advisor certification program is available throughout the region, with the private sector providing trained, certified experts throughout the Bay basin. In working with the agricultural community and private sector on nutrient management and soil conservation plans, integrated pest management planning could become a logical and integral component of whole farm planning efforts.

## Regulatory Program Implementation

Building on the progress of regulatory program implementation to date, the revised strategy needs to be consistent with and supplement existing state, federal, and local legislative and regulatory mandates. Regulatory programs should be targeted towards Bay toxics problems identified through the strategy reevaluation and, therefore, place emphasis on Regions of Concern, Toxics of Concern, and inventoried sources with significant chemical contaminant loadings or releases.

Future revisions of the Toxics of Concern List should include the latest information on point and nonpoint source loadings, ambient concentrations, aquatic toxicity, and federal and state regulations and/or restrictions. The process for reviewing and revising the Toxics of Concern List (i.e., adding or removing chemicals from the list) must be based on an objective risk-based ranking system followed by professional interpretation of the resultant rankings. Revision of the Toxics of Concern List should also include identification of Chemicals of Potential Concern for the Chesapeake Bay basin.

Increased reliance on the identified Toxics of Concern and Chemicals of Potential Concern would enable agency managers to anticipate (rather than react to) chemical-specific related issues. Possible actions range from aggressive implementation of a pollution prevention program targeted at specific sources of identified chemical contaminants to the implementation of discharge permit limits before the targeted chemical contaminants become widespread in the Bay basin environment.

## **Regional Focus**

The most severe chemical contamination problems in the Chesapeake Bay are limited to those areas located near urban centers close to the Bay—the Patapsco, Anacostia, and Elizabeth rivers. Through the strategy reevaluation process, an in-depth analysis of existing data has identified other Bay habitats where lower concentrations of chemical contaminants may have a chronic effect (i.e., reduced growth or reproduction) rather than an acute impact (i.e., death) or where present activities may lead to the development of chemical contaminant-related problems if action is not taken now.

Without a geographical focus the revised strategy could cover too many areas and issues to be effective. The identification of Regions of Concern will narrow the scope to definable areas on which to focus specific actions. At the same time, the Regions of Concern approach is meant to go beyond obvious sites of chemical contamination to include less affected where there is evidence of potential chemical contaminant-related impacts. These areas would be identified as Areas of Emphasis and targeted for more pollution prevention-oriented actions. The identification of Regions of Concern and Areas of Emphasis will clarify the geographic extent of Chesapeake Bay toxic problems and establish a basis for targeting remediation, reduction, and prevention actions and defining future assessment, monitoring, and research priorities.

## **Directed Toxics Assessments**

The strategy reevaluation revealed that the potential exists for low levels of chemical contaminants to adversely affect aquatic organisms in many Bay habitats. These levels are concentrations lower than thresholds generally associated with known toxic effects on living resources (e.g., EPA aquatic life criteria and state water quality standards) but elevated above natural background levels (e.g., enrichment of metal concentrations in sediment above natural earth crustal levels). Future assessments must continue to focus on evaluating the risks posed to the Bay's living resources due to low level chemical contaminant exposure, including the potential for additive or synergistic effects from multiple chemical contaminants using chemical and biological methods with sufficient sensitivity to detect these effects.

Future assessment must also be directed toward better quantifying sources of these chemical contaminants. The reported loadings and releases for many of the sources inventoried in the *Chesapeake Bay Basinwide Toxics Loading and Release Inventory* were not collected to calculate load or release estimates, but to assess compliance (e.g., point sources), use patterns (e.g., pesticide applications), or for other purposes. To develop a comprehensive baseline of chemical contaminant loadings and releases to the Bay basin, a number of specific actions must be taken to collect the data necessary to estimate loadings and releases with increased certainty.

As increasingly stringent controls are applied to point sources of chemical contaminants, the relative importance of nonpoint sources (e.g., urban stormwater runoff) is increasing. Nonpoint sources are diffuse and, therefore, much harder to track and control. A mass balance framework

quantifying the amount of chemical contaminants entering and leaving the Bay system, could be used to target further source reduction efforts more precisely.

The mass balance approach should be an integral part of the Regions of Concern component of the revised strategy. This approach should serve as a framework for identifying the relative importance of various sources of chemical contaminant impacts so that effective risk-reduction strategies can be developed. As this approach takes hold in the various Regions of Concern, it may point toward more comprehensive risk management strategies for the basin as a whole.

## **Revising the Basinwide Strategy**

The process for revising the basinwide strategy will incorporate public involvement in the strategy's development, review, and implementation. The revised strategy will build upon the findings from the strategy reevaluation and be structured around the Executive Council's four areas of emphasis. Following a series of stakeholder roundtables and a public review of the draft strategy document, the final strategy will be presented to the Chesapeake Executive Council at their 1994 annual meeting for signature and adoption by the Chesapeake Bay Agreement signatories.

---

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Many scientists, program managers, and technical staff from the various universities, state, federal, and regional agencies, environmental organizations, and scientific and citizen advisory groups involved in the Chesapeake Bay Program's restoration and protection activities contributed time, expertise, text, and data in the production and review of this reevaluation report. In alphabetical order, these individuals were: Fatina Abdaoui, U.S. Environmental Protection Agency; Ray Alden, Old Dominion University; Joel Baker, University of Maryland; Carol Ann Barth, Alliance for Chesapeake Bay; Richard Batiuk, U.S. Environmental Protection Agency; Dean Baudler, Computer Sciences Corporation; Bette Bauereis, Baltimore Gas and Electric Company; Dave Bingaman, Pennsylvania Department of Agriculture; Al Bromberg, New York State Department of Environmental Conservation; Elizabeth Chatfield, West Virginia State Water Resources Board; Tom Church, University of Delaware; Jeff Cornwell, University of Maryland; Robert Croonenbergs, Virginia Department of Health; Francisco Cruz, U.S. Environmental Protection Agency; Therese Dougherty, U.S. Environmental Protection Agency; Dan Drawbaugh, Pennsylvania Department of Environmental Resources; Kelly Eisenman, Chesapeake Research Consortium; Richard Eskin, Maryland Department of the Environment; Elliot Finkelstein, Alliance for the Chesapeake Bay; Nina Fisher, Technical Writing and Graphic Design Services; Fran Flanagan, Alliance for Chesapeake Bay; Bob Foley, U.S. Fish and Wildlife Service; Greg Foster, George Mason University; Dana Frye, Chesapeake Research Consortium; Mary Jo Garreis, Maryland Department of the Environment; Lenwood Hall, University of Maryland; Ian Hartwell, Maryland Department of Natural Resources; Mike Hirshfield, Chesapeake Bay Foundation; Ed Johnson, U.S. Department of Agriculture; Nick Kauffman, District of Columbia Department of Consumer and Regulatory Affairs; John Kennedy, Virginia Department of Environmental Quality; Anita Key, District of Columbia Department of Consumer and Regulatory Affairs; Marvin Lawson, Virginia Department of Agricultural and Consumer Services; Diane Leister, University of Maryland; Catherine Libertz, U.S. Environmental Protection Agency; Betty Marose, University of Maryland; Joe Macknis, U.S. Environmental Protection Agency; Eli McCoy, West Virginia Department of Natural Resources; Israel Milner, U.S. Environmental Protection Agency; Cherie Miller, U.S. Geological Survey; Maggie Moulton, Professional Desktop Solutions; Kent Mountford, U.S. Environmental Protection Agency; Deirdre Murphy, Maryland Department of the Environment; Steve Nelson, Chesapeake Research Consortium; Tom O'Connor, National Oceanic and Atmospheric Administration; Harriette Phelps, University of the District of Columbia; Scott Phillips, U.S. Geological Survey; Alan Pollock, Virginia Department of Environmental Quality; Chuck Prorok, Computer Sciences Corporation; Bill Rickards, Virginia Sea Grant Program; Kathy Rowland, Maryland Department of the Environment; Jim Sanders, Academy of Natural Sciences; Jackie Savitz, Chesapeake Bay Foundation; Lydia Schlosser, U.S. Department of Agriculture; Mari Schwoyer, Computer Sciences Corporation; Joe Scudlark, University of Delaware; Mary Ellen Setting, Maryland Department of Agriculture; Brad Smith, Delaware Department of Natural Resources and Environmental Control; Gary Speiran, U.S. Geological Survey; Marcia Spink, U.S. Environmental Protection Agency; Peter Tinsley, Maryland Department of the Environment; Debra Trent, Virginia Department of Environmental Quality; Mike Unger, Virginia Institute of Marine Science; Nathalie Valette-Silver, National Oceanic and Atmospheric Administration; Dave Velinsky, Interstate Commission on the Potomac River Basin; Betsy Weisengoff, Maryland Department of the Environment; Heather Westra, Chesapeake Research Consortium; William Whitney, Chesapeake Bay Program Citizens Advisory Committee; and Linda Zynjuk, U.S. Geological Survey.

## Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

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# BASINWIDE STRATEGY REEVALUATION

## Basinwide Toxics Reduction Strategy

In signing the 1987 Chesapeake Bay Agreement, Pennsylvania, Maryland, Virginia, the District of Columbia, the U.S. Environmental Protection Agency, and the Chesapeake Bay Commission committed to:

*“by December 1988, to develop, adopt and begin implementation of a basinwide strategy to achieve a reduction of toxics, consistent with the Clean Water Act of 1987, which will ensure protection of human health and living resources. The strategy will cover both point and nonpoint sources, monitoring protocols, enforcement pretreatment regulations and methods for dealing with in-place toxic sediments where necessary.”*

Signed by the Chesapeake Executive Council in January 1989, the resultant *Chesapeake Bay Basinwide Toxics Reduction Strategy* initiated a multi-jurisdictional effort to define the nature, extent, and magnitude of Chesapeake Bay toxics problems more precisely [53]. Building on the existing state and federal regulatory and management programs, the strategy used requirements of the 1987 Clean Water Act as a foundation for the actions needed to reduce loadings of potentially toxic chemicals to the Chesapeake Bay.

## Strategy Reevaluation

The basinwide strategy included a commitment to reevaluate the strategy by December 1992. The Chesapeake Bay Program's Toxics Subcommittee initiated the strategy reevaluation in January 1992 to more clearly define the nature, extent, and magnitude of Bay toxics problems. In addition to presenting new information of both the impact and the potential for impact of potentially toxic chemicals on the Bay ecosystem, this report also provides examples of progress to-

wards implementation of the basinwide strategy and achievement of the strategy's interim and long-term goals. The current understanding of specific Bay toxics problems is reflected in recommended refinements to the basinwide strategy.

## Reevaluation Objectives

The general objectives of the Basinwide Toxics Reduction Strategy Reevaluation were to define what is currently known, the steps that should be taken to reduce existing and prevent future impacts from chemical contaminants, and those aspects that should be better understood to implement further basinwide, regional, and local reduction and prevention actions. Specifically, the report's objectives are to:

- Answer, to the extent possible, the question, “What are the nature, extent, and magnitude of Chesapeake Bay toxics problems”?
- Assess the relative importance (e.g., risk to Bay living resources) of defined Bay toxics problems.
- Clarify the gaps in knowledge and the necessary steps to address these gaps.
- Document findings that redirect the existing basinwide strategy towards targeted implementation of reduction and prevention actions.

## Reevaluation Process

The Chesapeake Bay Program's Toxics Subcommittee set up a 20-month schedule of strategy reevaluation theme-oriented meetings, research workshops, and information-gathering forums which reflected the diverse, and often complex, nature of Bay toxics issues (Table 1). The objectives of the strategy reevaluation process (as previously stated) were coupled with directed efforts to:

- Review the implementation status of all basinwide strategy commitments;

## Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

- Evaluate findings from past and ongoing toxics-related research, monitoring, assessment, implementation, and prevention projects sponsored by the Chesapeake Bay Program;
- Review existing regional/national regulatory and management program directions as foundation to recommend refinements to the basinwide strategy; and
- Identify strategy commitments which require a change in emphasis and identify areas not recognized within the existing basinwide strategy which should be emphasized.

The Toxics Subcommittee's sponsorship of seven critical issue forums—wildlife contamination, pesticides, groundwater loadings, atmospheric deposition of toxics, sediment contamination, finfish/shellfish tissue contamination, and water column contamination—was key in building a technical consensus on the findings reported here.

These critical issue forums were structured to assess the nature, extent, and magnitude of Bay toxics problems.

Regional and national technical experts were invited to work with the Toxics Subcommittee in these one-day forums to analyze what available data reveal about possible adverse impacts on Bay living resources and human health due to exposure to chemical contaminants. Each critical issue forum was structured around a common set of questions (Table 2). Proceedings for each critical issue forums have been published and widely distributed (Table 3).

Throughout the strategy reevaluation process, the Toxics Subcommittee ensured active involvement of the Chesapeake Bay Program's scientific and citizens advisory committees and targeted the general public for participation in all subcommittee-sponsored meetings, forums, and

**Table 1.** Basinwide Toxics Reduction Strategy reevaluation schedule: meeting themes, critical issue forums, and workshops. Source: Chesapeake Bay Program Toxics Subcommittee, 1993.

1991	
October	Chesapeake Bay Wildlife Contamination Critical Issue Forum
1992	
January	Meeting Theme: Point sources, urban runoff, hazardous wastes
February	Chesapeake Bay Toxics Research Program Workshop
April	Chesapeake Bay Pesticide Critical Issue Forum
April	Chesapeake Bay Groundwater Toxics Loading Workshop
May	Meeting Theme: Water quality standards, living resource habitat needs
June	Meeting Theme: Non-traditional sources review
September	Meeting Theme: Toxics research findings and directions
October	Meeting Theme: Pollution prevention directions, public communication
November	Chesapeake Bay Atmospheric Deposition Critical Issue Forum
December	Chesapeake Bay Contaminated Sediments Critical Issue Forum
1993	
January	Meeting Theme: Reevaluation findings and new strategy directions
March	Chesapeake Bay Finfish/shellfish Critical Issue Forum
April	Chesapeake Bay Water Column Contaminants Critical Issue Forum
May	Chesapeake Bay Toxics Research Workshop

**Table 2.** Chesapeake Bay toxics critical issue forum questions.

From the critical review of available data, have we defined/can we define the relative magnitude and extent of [toxic issue] within Chesapeake Bay?

Does this definition of the magnitude and extent of [toxic issue] within the Bay give us reason to believe this identified (potential) toxic issue is causing or can cause an impact on the Chesapeake Bay system, on either a Baywide, regional, or local scale?

How does the magnitude of [toxic issue] within Chesapeake Bay compare with other coastal systems (e.g., Puget Sound) or large water bodies (e.g., Great Lakes)?

What direction should the Toxics Subcommittee recommend the Chesapeake Bay Program agencies take with regards to addressing [toxic issue]?

If there is insufficient data or information to answer the above questions, identify the additional data/research required to answer the questions.

workshops. As the reevaluation report was being drafted, the Toxics Subcommittee continued to solicit feedback on its preliminary findings and recommendations.

## Report Structure and Content

Findings characterizing Bay toxics problems are presented in a sequence which reflects the movement of chemical contaminants from their original sources, through the watershed, and ultimately into the Bay's tidal waters, sediments, and biota. Descriptions of the chemical contaminant concentrations in Bay habitats are followed by documented evidence of adverse effects due

to exposure to these chemical contaminants (Chapter 2). Descriptions of progress by existing regulatory and management programs throughout the Bay basin (Chapter 3) are followed by specific examples of environmental responses which illustrate the effectiveness of past and present reduction and prevention actions (Chapter 4). Chapter 5 highlights and describes those areas requiring emphasis in the revised basinwide strategy, building on the increased understanding of Bay toxics problems and progress. The report concludes with a summary of the process and schedule for revising the basinwide strategy (Chapter 6).

**Table 3.** Chesapeake Bay toxics critical issue forums.

<u>FORUM PROCEEDINGS</u>	<u>FORUM DATE</u>	<u>REFERENCE</u>
Status and Assessment of Chesapeake Bay Wildlife Contamination	November 1991	CBP (1992b)
Chesapeake Bay Groundwater Toxics Loading Workshop Proceedings	April 1992	CBP (1993c)
Chesapeake Bay Atmospheric Deposition of Toxics Critical Issue Forum Proceedings	November 1992	CBP (1993a)
Chesapeake Bay Sediment Contamination Critical Issue Forum Proceedings	December 1992	CBP (1992d)
Chesapeake Bay Finfish/Shellfish Tissue Contamination Critical Issue Forum Proceedings	March 1993	CBP (1993b)
Chesapeake Bay Water Column Contaminants Critical Issue Forum Proceedings	April 1993	CBP (1993e)



## DEFINING BAY TOXICS PROBLEMS

Since the first multi-jurisdictional investigations into Bay toxics problems (included in the 1975-1983 Chesapeake Bay Program's research phase) [292, 293, 294], significant progress has been made towards answering the question "What are the nature, extent, and magnitude of Bay toxics problems?". The following sections synthesize the current knowledge, limits of this knowledge, and gaps in our understanding of the Bay's toxics problems. This information sets the stage for taking additional actions necessary to minimize the impact from exposure to chemical contaminants and for preventing future toxics problems through a revised basinwide strategy. It also directs Bay basin managers and scientists towards a more focused set of questions and issues requiring further study.

From 1,1' oxybisbenzene to zirconium, over 1000 chemical contaminants have been detected in, released to, or applied to the water, soil, sediment, tissue, or air within the Chesapeake Bay basin. A compound's inclusion on this comprehensive list of chemical contaminants does not constitute evidence of potential or existing environmental impact [43]. It merely documents a measurement of that chemical contaminant in some environmental media at some time in the past. This list contains the chemical contaminants which will be ranked and identified as part of the process for making future revisions to the Chesapeake Bay Toxics of Concern List. The Chesapeake Bay Program's Toxics Data Base stores both the list and supporting documentation.

**Table 4.** Chesapeake Bay Toxics of Concern List.

Atrazine	Chrysene	Mercury
Benzo[a]anthracene	Chromium	Naphthalene
Benzo[a]pyrene	Copper	PCBs
Cadmium	Fluoranthene	Tributyltin
Chlordane	Lead	

Source: Chesapeake Bay Program 1991a.

## Chesapeake Bay Toxics of Concern

The difficulty in clearly defining Bay toxics problems is largely due to the overwhelming number of chemicals used by society. Over 4 million compounds are known to exist; about 75,000 are now in commercial use with nearly 1,000 new compounds developed each year.

The first Chesapeake Bay Toxics of Concern List, developed by the Chesapeake Bay Program Toxics and Living Resources Subcommittee's Criteria and Standards Workgroup, was published in 1991 (Table 4) [40]. The Criteria and Standards Workgroup finalized its development approach with a publicly reviewed workplan in October 1989. After months of collecting data and analyzing chemical ranking systems, ambient chemical contaminant concentrations, and

### Box 1. Sources of information on Chesapeake Bay Toxics of Concern

Chesapeake Bay Toxics of Concern List [40]  
Chesapeake Bay Toxics of Concern List Information Sheets [41]  
Comprehensive List of Chesapeake Bay Basin Toxic Substances [43]

**Table 5.** Chesapeake Bay Secondary List of Toxic Substances.

Alachlor	Dieldrin	Permethrin
Aldrin	Fenvalerate	Toxaphene
Arsenic	Metolachlor	Zinc

Source: Chesapeake Bay Program 1991a.

aquatic toxicity data, the workgroup identified those chemical contaminants representing a significant immediate or potential threat to the Chesapeake Bay system. The Toxics Subcommittee and the Living Resources Subcommittee approved this list and supporting information, with final approval by the Chesapeake Bay Program's Implementation Committee in January 1991.

Information sheets summarizing relevant information for each of the 14 chemical contaminants were published to support management use of the Toxics of Concern List [41]. A Secondary List identified those chemical contaminants which may ultimately be considered for inclusion in a future Toxics of Concern List based on the collection and interpretation of additional data and information (Table 5).

The basinwide strategy committed the Chesapeake Bay Agreement signatories to review and revise the Toxics of Concern List every two years (or as necessary) after development of the initial list. The Criteria and Standards Workgroup re-

viewed the Toxics of Concern List within one year (spring 1992) to institutionalize a more comprehensive ranking and selection process. This effort did not progress far as only limited data were available in the Chesapeake Bay Program Toxics Data Base which was under development at the time. The Criteria and Standards Workgroup did, however, review new information concerning diflubenzuron (dimilin) and carbofuran. The workgroup recommended that diflubenzuron be deleted from the list of candidates for future addition to the Toxics of Concern List and that carbofuran not be considered for addition to the Secondary List.

The Chesapeake Bay Program developed the Toxics of Concern List principally to identify and provide concise documentation on chemical contaminants that adversely impact the Bay or have a reasonable potential to do so. This list has provided Chesapeake Bay region resource managers and regulators with a baywide consensus of priority chemicals and the information necessary to target these chemical contaminants for additional research, monitoring, and assessment or

**Box 2. Sources of information on Chesapeake Bay basin loadings and releases**

*Agricultural Pesticide Use in Coastal Areas: A National Summary* [228]  
*Annual Loading Estimates of Urban Toxic Pollutants in the Chesapeake Bay Basin* [224]  
*Atmospheric Deposition of Nitrogen and Contaminants to Chesapeake Bay and its Watershed* [304]  
*Chesapeake Bay Atmospheric Deposition of Toxics Critical Issue Forum Proceedings* [45]  
*Chesapeake Bay Atmospheric Deposition Study Reports* [11,12,14,70,174,274,341]  
*Chesapeake Bay Basin Toxics Loading and Release Inventory* [50]  
*Chesapeake Bay Basin Toxics Loading and Release Inventory: Technical Update—Point Sources by Facility* [51]  
*Chesapeake Bay Fall line Toxics Monitoring Program Reports* [193,194,195]  
*Chesapeake Bay Groundwater Toxics Loading Workshop Proceedings* [46]  
*Identification of Sources Contributing to the Contamination of the Great Waters by Toxic Compounds* [165]  
*Local Solutions - A Local Government Guide to Managing Household Hazardous Waste in the Chesapeake Bay Region* [39]  
*Lower Patapsco River/Baltimore Harbor Contaminant Data Base Assessment Project* [317]  
*Occurrence and Distribution of Pesticides in Chesapeake Bay* [163]  
*Relative Loadings of Toxic Contaminants and Nitrogen to the Great Waters* [13]  
*Report to Congress: Deposition of Toxic Air Pollutants to the "Great Waters"* [300]  
*Sources, Cycling and Fate of Contaminants in Chesapeake Bay* [259]



**Table 6.** Chesapeake Bay basin state water quality standards adopted and EPA aquatic life criteria published for Chesapeake Bay Toxics of Concern.

Chesapeake Bay Toxics of Concern	NY	PA	MD	DC	VA	WV	DE	U.S. EPA Criteria <sup>1</sup>
Atrazine								2
Benzo[a]anthracene	5	✓			4			
Benzo[a]pyrene	5	4			4		4	
Cadmium	✓	✓	✓	✓	✓	✓	✓	✓
Chlordane	5	✓		✓	✓	✓	✓	✓
Chromium	✓	✓	✓	✓	✓	✓	✓	✓
Chrysene	5	4			4			
Copper	✓	✓	✓	✓	✓	✓	✓	✓
Fluoranthene	5	✓		✓	4		4	3
Lead	✓	✓	✓	✓	✓	✓	✓	✓
Mercury	4	✓	✓	✓	✓	✓	✓	✓
Naphthalene	4	✓		✓				3
PCBs	✓	✓	✓	✓	✓	✓	4	✓
Tributyltin	5		✓		✓			✓

✓ = Water quality standard adopted; aquatic life quality criteria published.

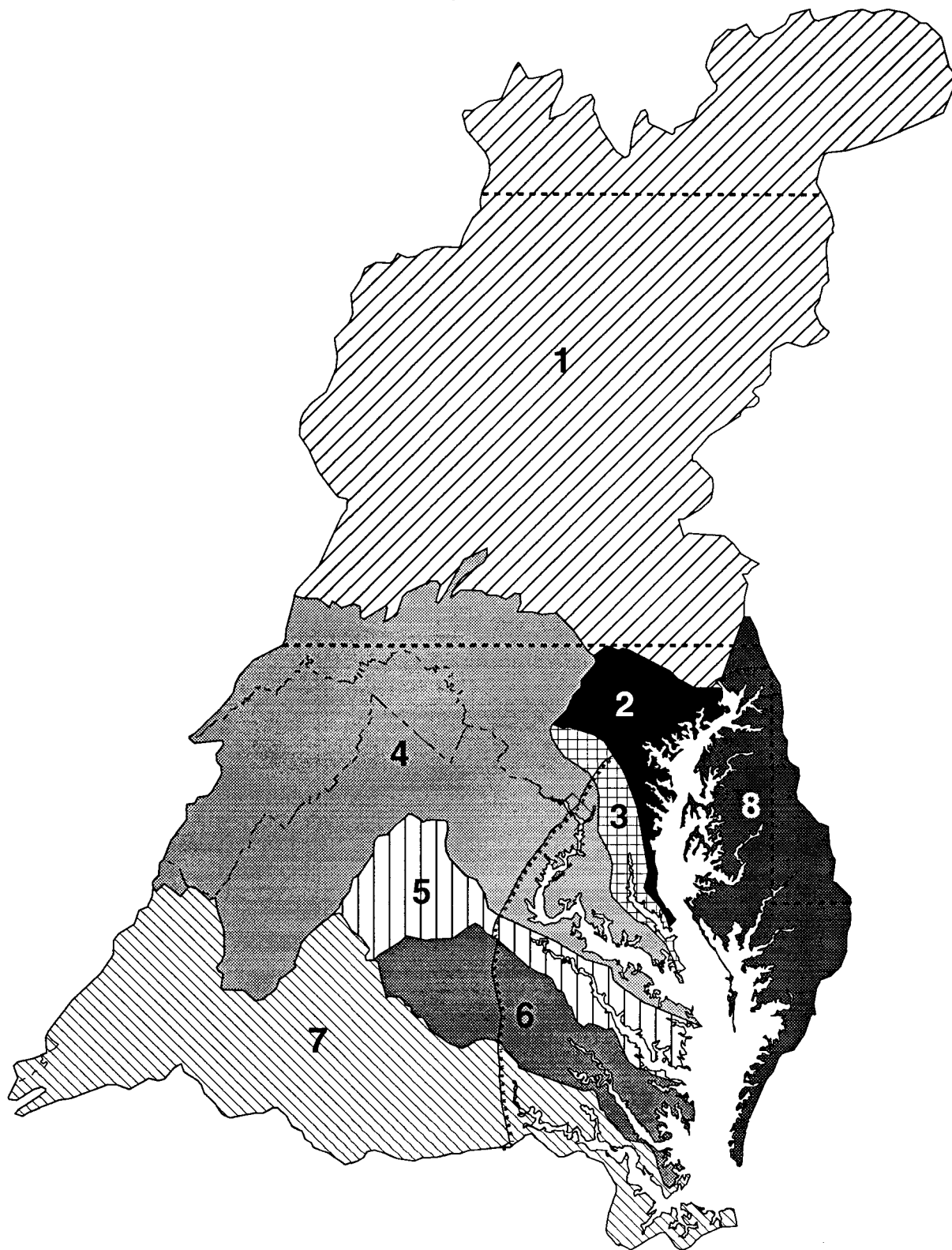
1. U.S. EPA freshwater and marine, acute and chronic aquatic life criteria.
2. Freshwater and marine aquatic life criteria for atrazine current under development by U.S. EPA; Chesapeake Bay Program has funded development of an estuarine atrazine aquatic life criteria.
3. Insufficient data to develop criteria; U.S. EPA has published a lowest observed effect level.
4. Water quality standard adopted for protection of human health only.
5. Surface water human health guidance value; used in writing permits.

Sources: Chesapeake Bay Program 1991a; U.S. Environmental Protection Agency 1994a.

strengthened regulatory and prevention actions. Efforts have focused on the development of water quality criteria and the promulgation of water quality standards for the Toxics of Concern. Since publication of the initial Chesapeake Bay Toxics

of Concern List, all the Bay basin jurisdictions have adopted several water quality standards for many of the chemical contaminants on the list (Table 6).

### Chesapeake Bay Basin Watersheds



**Figure 1.** Chesapeake Bay basin watersheds: Susquehanna (1), West Chesapeake (2), Patuxent (3), Potomac (4), Rappahannock (5), York (6), James (7), and Eastern Shore (8). Bay fall line boundary indicated by "toothed line" (TTTT).

## Bay Basin Loadings and Releases

Published in March 1994, the *Chesapeake Bay Basin Toxics Loading and Release Inventory* is the first step in the Chesapeake Bay Agreement signatories commitment to establish a comprehensive baseline on point and nonpoint source loadings of potentially toxic chemicals to the Bay basin (Figure 1) [50]. The estimated loadings and releases described in the initial inventory report (summarized here) are not measures of absolute loadings or releases from the different sources and are not the comprehensive baseline of loadings and releases envisioned in the original basinwide strategy commitment. Due to limitations in the available data, the estimated loadings and releases underestimate or overestimate actual loadings and releases and are limited to a small subset of the more than 1,000 potentially toxic chemicals identified within the Bay watershed.

The inventory structure provides relative comparisons among sources only at the order-of-magnitude scale due to variation in both the availability and quality of data for each of the sources and uncertainties in the loading and release estimates. Often these estimates were developed using limited data from a variety of sources of uncertain quality and confidence levels, covering various time periods, and collected for purposes other than to calculate loadings and releases. At this early stage in the development of a more precise inventory baseline, larger estimates of loadings or releases may indicate a more complete or comprehensive data base rather than identification of a major source.

Because of the broad scope of the inventory, multiple data sources, and differing data quality, numerous limitations exist and must be considered when using the data. The inventory's estimated loadings and releases do not account for transformations or degradations that may occur during transport from sources discharging to non-tidal

waters. Despite such limitations, direct comparisons of loadings within and between source categories can assist in understanding order-of-magnitude differences. Releases (estimates of the amounts of chemicals emitted within or applied to the land within the Bay's watershed) should not be directly compared with estimated loadings. Estimated loadings and releases are presented only for Toxics of Concern and Secondary List chemicals. Combined loadings or releases for all chemicals were not compared since there was no common set of chemicals with estimated loadings or releases between sources and across different basins.

### Above Fall Line Loadings

The fall line, usually characterized by waterfalls, demarcates the geologic boundary between the unconsolidated sediments of the Coastal Plain and the hard crystalline rock of the Piedmont. The fall line can also mark the upriver limit of tidal influence. Many cities, including Baltimore, Richmond, Fredericksburg, and Washington, DC, were established near the fall line to take advantage of the water energy for power generation and transportation.

Loadings to above fall line waters do not represent loads directly entering the tidal waters of the Chesapeake Bay. These loads to non-tidal tributaries are diminished by chemical and physical degradation enroute to the fall line, where they are measured as part of the total point and nonpoint source load.

### POINT SOURCE DISCHARGES - ABOVE FALL LINE

The public generally recognizes point sources more easily than other sources of pollution because these wastes are generated within a limited, defined area and are generally discharged through a pipe. Point sources may also release pollutants to the air or may be transferred off-site for treatment or disposal. Within the inventory, point sources were limited to industrial, municipal, and

federal facilities which discharge chemicals directly to tidal and nontidal surface waters.

Industrial point sources have the potential to release many of the raw materials, catalysts, solvents, and other chemicals used in the manufacture of finished products and materials to the water, land, and air. Municipal point sources may receive and then discharge chemicals originating from industrial sources or household use. Many industries transfer their wastes, which may contain metals, organic compounds, and other chemicals, to municipal wastewater treatment plants. Some of the chemicals in these wastes are incompatible with normal wastewater treatment processes and may interfere with the treatment process, pass through to surface waters untreated, or be removed from the waste stream and deposited in the sludge. Chemical contaminants may also be produced during treatment at the wastewater treatment plant as by-products of chlorine disinfection.

Federal facilities are often involved in manufacturing and waste-generating activities similar to those of privately-owned industrial facilities or publicly-owned municipal wastewater treatment facilities. In the inventory, federal facilities are treated the same as municipal or industrial dischargers for point source load estimation.

There are over 6,000 industrial, municipal, and federal point source dischargers within the Chesapeake Bay basin [50]. Of these, 320 are classified as "major" dischargers. The inventory includes loadings estimates from nearly one third of these major dischargers (Figure 2).

Pennsylvania point source estimates include 304(l)-designated industrial and municipal dischargers based on 1992 data. Maryland point source estimates include 304(l)-designated industrial dischargers based on 1989 data, Baltimore Harbor industrial dischargers based on 1984 to 1989 data, and municipal dischargers based on 1992 data. The District of Columbia's point source estimates include only the Blue Plains

Municipal Treatment Plant and are based on 1990 data. Virginia point source estimates include only 304(l)-designated industrial and municipal dischargers based on data from 1980-1989. In addition, point source loading estimates from 304(l)-designated facilities in West Virginia were included in the above fall line point source loadings for the Potomac River basin.

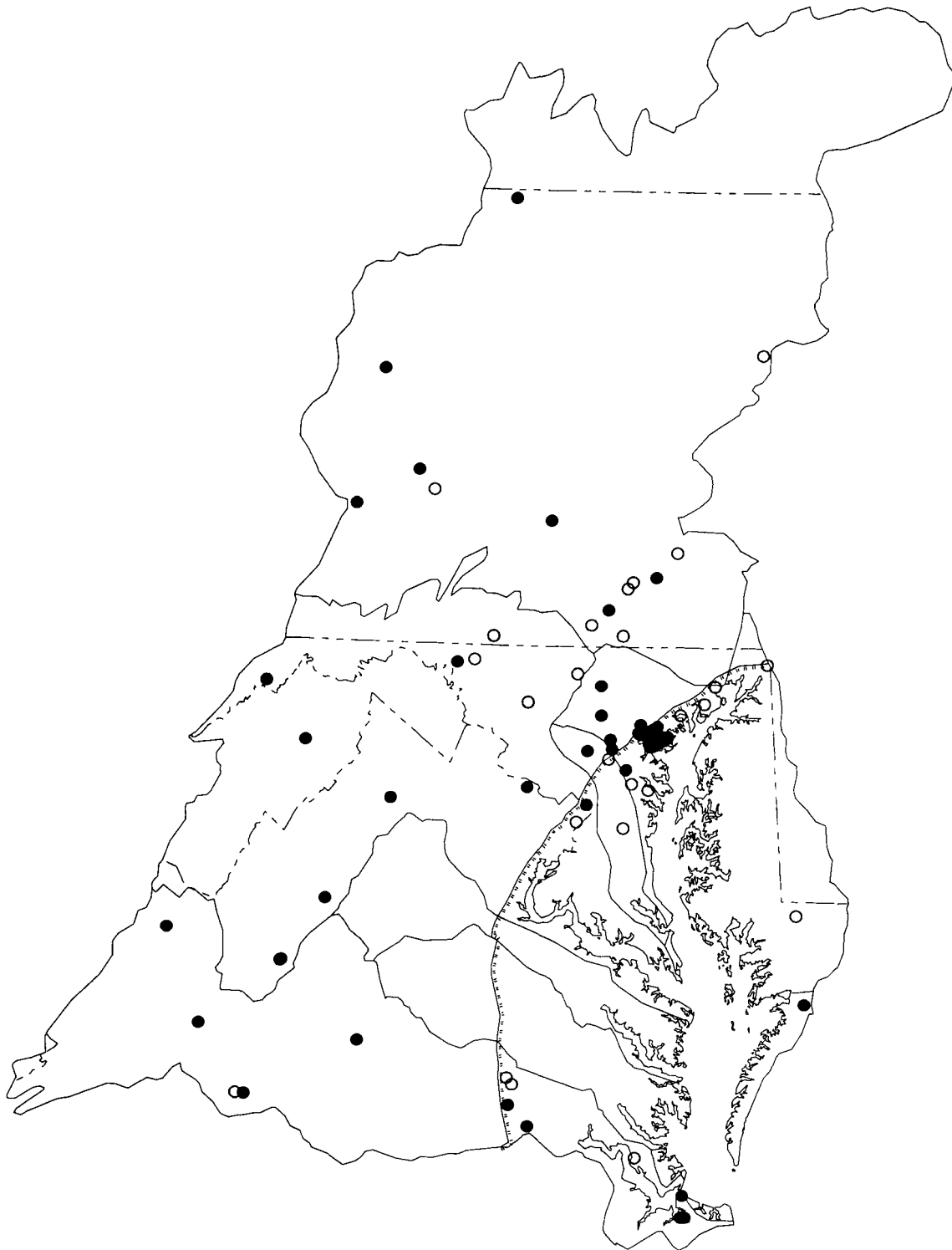
The inventory's point source loading estimates include industrial, municipal, and federal point source discharges to surface waters of the Chesapeake Bay and its tidal and non-tidal tributaries. The focus of these estimates is on process wastewater, but some of the estimates include cooling water discharges or industrial stormwater outfalls.

In response to a Chesapeake Executive Council Directive, the inventory was expanded to include estimates at the facility level [54]. Facility-level load estimates from 59 Pennsylvania industrial and municipal sources, 14 Maryland municipal sources, and 86 additional industry-reported loadings to surface waters from the national Toxics Release Inventory data base for all states in the Bay watershed were added to the inventory through a technical update [51].

The point source loading estimates are an underestimation of the total point source loads due to the limited number of facilities and chemicals inventoried. The estimates presented in the inventory may be based on only one or two monitoring sessions taken over several years since 1980 and which were intended to provide data for purposes other than load estimation (e.g., compliance). Nevertheless, they are based on measured chemical concentrations and volumes of wastewater discharged.

The largest above fall line point source discharges of Toxics of Concern and Secondary List chemicals were for metals, particularly zinc, copper, and chromium (Table 7). The largest estimated above fall line point source metal loadings were for the Potomac basin, followed by the

## Priority Chesapeake Bay Basin Point Source Discharges



**Figure 2.** Locations of the priority Chesapeake Bay basin point source municipal (○) and industrial (●) discharges as designated through the Chesapeake Bay Basinwide Toxics Loading and Release Inventory. Source: Chesapeake Bay Program 1994a.

Susquehanna and James basins. Estimated loadings of Toxics of Concern metals from point sources from above the fall line in the West Chesapeake, Patuxent, Rappahannock, and York basins totaled less than 140 pounds per year. There were no estimated loadings for the Toxics of Concern polycyclic aromatic hydrocarbons from above fall line point sources reported in the inventory (Table 7).

### **URBAN STORMWATER RUNOFF - ABOVE FALL LINE**

Urban stormwater runoff is a mixture of chemical contaminants washed from the urban and suburban landscape. The major sources of chemicals in urban runoff include incomplete combustion of fossil fuel, metal alloy corrosion, automobile-related activities, atmospheric deposition, pesticide use, naturally occurring crustal elements (e.g.,

metals), and industrial manufacturing activities (Table 8). Each unit area of urban land contributes varying amounts of surface runoff and chemicals.

The quality and quantity of the runoff is a function of several controlling variables including the percentage of impervious surface area, land use activity, automobile traffic density, degree of air pollution just prior to rainfall, rainfall pattern and intensity, and the presence of source area or outfall controls. The findings summarized here are based on a study to quantify urban stormwater pollutant loads for 35 chemicals and were presented in the report *Annual Loading Estimates of Urban Toxic Pollutants in the Chesapeake Bay Basin* [224]. Refinements were made to the organic compound loadings in the basin-wide inventory [50].

**Table 7.** Estimates of above fall line point source loads of Chesapeake Bay Toxics of Concern and Secondary List chemicals by major Chesapeake Bay basin<sup>1</sup>.

Chemical Category/ Chemical	Total AFL <sup>2</sup> Basinwide Loading	Susq.	West Chesapeake	Patuxent	Potomac	Rapp.	York	James
<b>Metals</b>								
Arsenic	1,125	825	— <sup>3</sup>	—	50	125	—	125
Cadmium	1,770	990	—	—	250	—	—	530
Chromium	12,320	8,400	—	—	3,360	—	—	560
Copper	37,200	12,000	—	—	22,800	—	—	2,400
Lead	10,350	6,210	—	—	2,300	—	—	1,840
Mercury	70	52	—	6	12	—	—	—
Zinc	115,200	33,600	—	—	76,800	—	—	4,800
<b>Pesticides</b>								
Aldrin	1	—	—	—	—	—	—	1

1. Estimated loadings are in pounds/year.
2. Above fall line.
3. "—" indicates no loadings were estimated within the Inventory.

Source: Chesapeake Bay Program 1994a, 1994b.

**Table 8.** Predominant sources of chemicals commonly measured in urban stormwater runoff<sup>1</sup>.

Chemicals	Predominant Sources to Urban Stormwater Runoff
<b>FOSSIL FUEL COMBUSTION</b>	
Chrysene .....	Product of the incomplete combustion of fossil fuels, especially wood and coal burned in residential home heating units.
Fluoranthene .....	
Phenanthrene	
Pyrene	
Arsenic .....	Products of fossil fuel combustion.
Nickel	
<b>GASOLINE CONSUMPTION</b>	
Cyanides .....	Products of gasoline combustion.
<b>METAL ALLOY CORROSION</b>	
Cadmium .....	Metals released from the corrosion of alloys and plated surfaces and from electroplating wastes.
Chromium	
Copper .....	Metal released from the corrosion of copper pipes and fittings, auto brake linings, and electroplating wastes. Copper is also commonly used in algicides.
Zinc .....	Weathering and abrasion of galvanized iron and steel (such as aging pipes and gutters).
<b>AUTOMOBILE RELATED ACTIVITIES</b>	
Cyanides .....	Anti-caking ingredients in road salts.
Cadmium .....	Component of motor oil
Zinc .....	Component of automobile tires and a common ingredient in road salt.
<b>PESTICIDE USE</b>	
a-Hexachlorocyclohexane .....	Components commonly used in soil treatment to eliminate nematodes and for other pesticide uses.
y-Hexachlorocyclohexane	
Chlordane	
a-endosulfan	
Pentachlorophenol .....	Primarily used to protect wood products from microbial and fungal decay. Telephone poles are commonly treated with pentachlorophenol, for example.
4-Nitrophenol .....	Used in the manufacture of ethyl and methyl parathion.
<b>EXTERIOR PAINTS AND STAINS</b>	
Chromium .....	Components and pigments found in painting and staining products, however, use of several of these additives is being reduced or eliminated.
Lead	
Zinc	
Pentachlorophenol	
<b>PLASTIC PRODUCTS</b>	
Phenol .....	Used as an intermediate in the production of phenolic resins for plasticizers and other products. Phenol is also used to produce pharmaceuticals, germicides, fungicides, dyes, and some industrial acids.
Bis-(2-ethylhexyl) phalate .....	A widely used plasticizer (component which makes plastic flexible). It finds its way into urban runoff because, through time, it "leaches" from numerous plastic products (such as garden hoses, floor tiles, plastic containers, and food packaging).
<b>NATURALLY OCCURRING ELEMENTS</b>	
Antimony .....	Elements which occur naturally in rocks and soil.
Beryllium	
Selenium	

1. Priority pollutants detected in at least ten percent of National Urban Runoff Program urban runoff samples.

Source: Olsenholler 1991, adapted from Cole et al., 1983.

Urban stormwater runoff estimates of chemical contaminant loadings for the major sub-basins of the Chesapeake Bay drainage were developed for major urban land use categories by applying a load estimation model known as the Simple Method [271]. The Simple Method mathematically relates annual rainfall, a runoff coefficient (a linear function of watershed imperviousness), watershed area, and the flow-weighted mean concentration of a given chemical contaminant in runoff. The presented loading estimates reflect 1985 land use conditions for urban and suburban areas throughout the Bay watershed. While this loading estimation method allows urban stormwater runoff loads to be calculated from large areas, it does not account for site-specific variations. This method extrapolates a limited number of field-scale event data values to large-scale annual loadings and does not account for possible loadings from combined sewer overflows.

Large loadings of seven Toxics of Concern/Secondary List metals from urban stormwater runoff to above fall line surface waters were reported from all the major Chesapeake Bay basin, with estimated loadings of individual metals varying widely among the basins (Table 9). The highest estimated loads were reported for the Susquehanna followed by the Potomac, James, Patuxent, York, and Rappahannock basins.

Estimates of above fall line urban stormwater loadings include five polycyclic aromatic hydrocarbons on the Toxics of Concern List—benzo[a]anthracene, benzo[a]pyrene, chrysene, fluoranthene, and naphthalene. Basinwide loading estimates of above fall line loadings for these compounds ranged from 174 (benzo[a]anthracene) to 893 (naphthalene) pounds per year, with the highest estimated loads reported for the Susquehanna followed by the Potomac, James, Patuxent, York, and Rappahannock basins (Table 9).

### **ATMOSPHERIC DEPOSITION TO THE WATERSHED**

Atmospheric deposition, described in more detail on pages 27-29, is a source of chemicals to

both land (i.e., the entire Bay basin) and water surfaces (i.e., free-flowing rivers, lakes, and the Bay's tidal waters). Currently, only estimates of atmospheric deposition loading directly to Bay tidal surface waters can be made due to a lack of sampling stations located throughout the Bay watershed.

### **PESTICIDE MIXING AND LOADING FACILITIES**

The routine operation of pesticide mixing and loading facilities throughout the watershed may produce significant pesticide loadings to local and regional environments. The Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation became aware of this potential loading source through a program to monitor water quality improvements due to best management practices [311]. Based on the information collected at one site (described in more detail on pages 137-138) and the existence of over 300 facilities of this type in Virginia alone, the potential exists for large contributions of pesticides (and nutrients) to the surrounding environment during routine facility operation. Sufficient information does not currently exist, however, to determine the extent and magnitude of loadings of pesticides from these facilities.

### **HOUSEHOLD HAZARDOUS WASTES**

Household hazardous waste does not appear to be a significant source of chemical contaminant loadings to the Chesapeake Bay at the basinwide scale. With the increasing numbers of new products and the diverse users of these products, however, household hazardous waste may well pose a significant risk to local environments within the Chesapeake Bay basin when disposed of improperly (Figure 3) [39]. Currently, no estimates exist of the loadings from improper disposal of household hazardous waste to above fall line portions of the Bay basin.

### **AGRICULTURAL PESTICIDE WASTES**

Recent surveys in Virginia and Pennsylvania have shown that significant quantities of pesti-



cides are often stored on farms long-after they have become unusable, cancelled, or banned for use [27, 173]. These surveys, conducted through pilot pesticide collection and disposal programs in both states, listed the more prevalent pesticides targeted for proper disposal as DDT, endrin, lead arsenate, carbofuran, and several others. No loading estimates to the above fall line portion of the Bay basin from the storage of these pesticides exist, but spills have been recorded which severely impacted local stream habitats [27].

### ACID MINE DRAINAGE

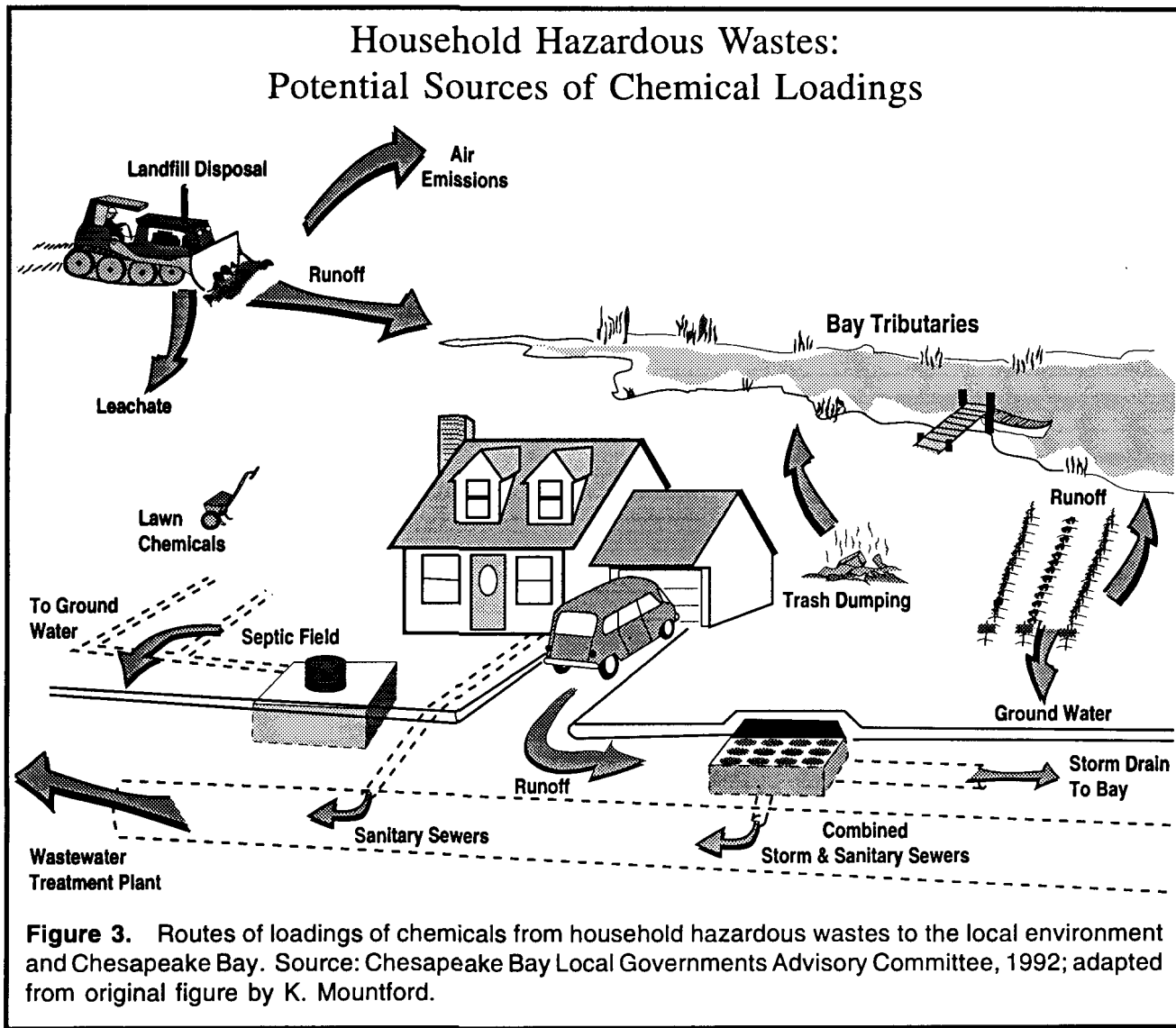
Within the Chesapeake Bay basin, problems associated with acid mine drainage (e.g., low pH and elevated water column concentrations of metals) appear to be localized in tributaries which are adjacent to and downstream of mine sites [270]. No estimates are available, however, on the potentially significant contribution of metals from mine drainage to the total loadings of metals at the Bay's tributary fall lines.

**Table 9.** Estimates of above fall line urban stormwater runoff loads of Chesapeake Bay Toxics of Concern and Secondary List chemicals by major Chesapeake Bay basin<sup>1</sup>.

Chemical Category/ Chemical	Total AFL <sup>2</sup> Basinwide Loading	Susq.	West Chesapeake	Patuxent	Potomac	Rapp.	York	James
<b>Metals</b>								
Arsenic	32,490	18,240	— <sup>3</sup>	1,140	8,550	570	570	3,420
Cadmium	7,980	4,480	—	280	2,100	140	140	840
Chromium	46,740	26,240	—	1,640	12,300	820	820	4,920
Copper	131,100	73,600	—	4,600	34,500	2,300	2,300	13,800
Lead	27,930	15,680	—	980	7,350	490	490	2,940
Mercury	1,482	832	—	52	390	26	26	156
Zinc	741,000	416,000	—	26,000	195,000	13,000	13,000	78,000
<b>PAHs</b>								
Benzo[a]anthracene	174	122	—	11	26	—	4	11
Benzo[a]pyrene	188	132	—	12	28	—	4	12
Chrysene	470	330	—	30	70	—	10	30
Fluoranthene	705	495	—	45	105	—	15	45
Naphthalene	893	627	—	57	133	—	19	57

1. Estimated loadings are in pounds/year.
2. Above fall line.
3. "—" indicates no loadings were estimated within the Inventory.

Source: Chesapeake Bay Program 1994a.



## Bay Basin Releases

### PESTICIDE APPLICATIONS

The use of pesticides for agricultural and non-agricultural purposes and the potential for these chemicals to adversely impact surface and groundwater quality is a concern of the Chesapeake Bay basin jurisdictions. Unlike other nonpoint sources of pollution, pesticides are intentionally applied for economic or otherwise beneficial purposes, such as protecting man, plants, and animals from insects, weeds, and diseases.

State pesticide usage surveys, which provide information to target areas for integrated pesticide management practices as well as surface and

groundwater monitoring programs, were used to estimate the quantities of pesticides used throughout the Pennsylvania, Maryland, and Virginia portions of the Chesapeake Bay basin. Funded through various state and federal sources, these surveys ranged from field use questionnaires generated from user interviews to estimates based on national data bases of crop acreage and product use [50]. Common parameters that the states selected in conducting the surveys were: pesticide active ingredient applied; rate of application; crop to which the application is made; and the number of acres to which the pesticide was applied. Modifications were made to these common elements to accommodate non-crop application sites and specialty applications.

Atrazine (2,300,000 pounds per year), metolachlor (2,300,000 pounds per year) and alachlor (1,400,000 pounds per year) were the Toxics of Concern/Secondary List pesticides with the highest basinwide application estimates (Table 10). These same three herbicides top the list of the ten pesticides with the highest estimated applications basinwide (in which a total of seven of the top ten pesticides were herbicides) (Table 11).

Herbicides accounted for 70 percent of the total usage of pesticides reported basinwide, followed by insecticides (20 percent), and fungicides (10 percent) (Table 12). The greater use of herbicides is clearly evident when comparing total estimated applications across the major Bay basins (Figure 4). The highest total pesticide applications were reported for the Potomac basin (which includes 22 percent of the total Bay watershed acreage), followed by the Eastern Shore (7.5 percent), Susquehanna (42 percent), James (46 percent), West Chesapeake (2 percent), Rap-

pahannock (5 percent), York (4 percent), and Patuxent (1.5 percent) basins (Table 12).

The Bay basin counties with the highest estimated pesticide applications are concentrated in the lower Susquehanna basin, middle and upper Potomac basin (i.e., up into the Shenandoah Valley), upper Patuxent basin, Rappahannock basin, and throughout Maryland and Virginia's Eastern Shore (Figure 5). Table 13 summarizes the principal crops and commonly applied pesticides for these high pesticide use regions.

In a 1992 report, the National Oceanic and Atmospheric Administration assessed pesticide usage within the coastal regions throughout the United States. The Chesapeake Bay ranked as the ninth highest in pesticides applied annually within the estuarine drainage area (the below fall line portion of the watershed) of the 67 estuarine and coastal systems assessed [228].

**Table 10.** Estimates of annual applications of Chesapeake Bay Toxics of Concern and Secondary List pesticides by major Chesapeake Bay basin<sup>1</sup>.

Chemical Category/ Chemical	Total Basinwide Application	Susq.	West Chesapeake	Patuxent	Potomac	Rapp.	York	James	Eastern Shore
<b>HERBICIDES</b>									
Alachlor	1,400,000	294,000	126,000	28,000	266,000	126,000	126,000	126,000	322,000
Atrazine	2,300,000	782,000	253,000	-	552,000	115,000	92,000	115,000	391,000
Metolachlor	2,300,000	713,000	253,000	23,000	506,000	69,000	46,000	69,000	644,000
<b>INSECTICIDES</b>									
Fenvalerate	6,800	68	1,088	-	2,584	-	-	-	3,128
Permethrin	31,000	930	18,600	-	1,550	2,790	3,410	2,480	930
<b>FUNGICIDES</b>									
Copper	10,000	- <sup>2</sup>	-	-	900	1,200	1,100	1,800	4,800

1. Estimated applications are in pounds/year of active ingredient.

2. "-" indicates no loadings were estimated within the Inventory.

Source: Chesapeake Bay Program 1994a.

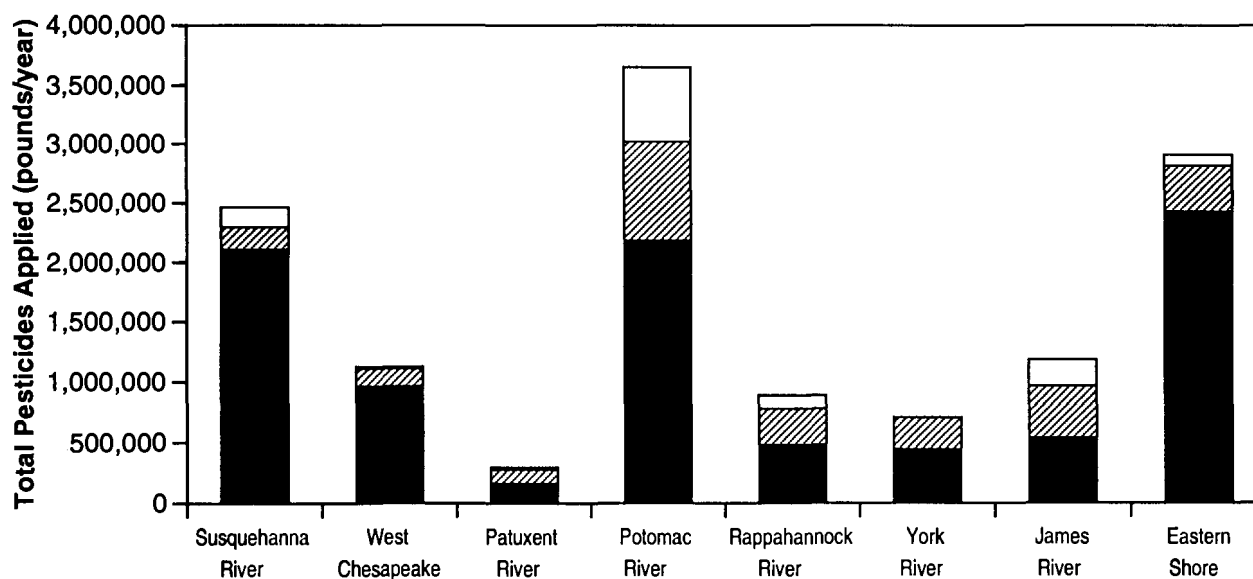
**Table 11.** Pesticides with the highest estimated annual applications within the Chesapeake Bay basin.

Pesticide	Total Basinwide Application <sup>1</sup>	Class
Atrazine	2,300,000	Herbicide
Metolachlor	2,300,000	Herbicide
Alachlor	1,400,000	Herbicide
Carbofuran	680,000	Insecticide
Cyanazine	570,000	Herbicide
Captan	540,000	Fungicide
Simazine	390,000	Herbicide
Linuron	380,000	Herbicide
Chloropyrifos	360,000	Insecticide
2,4-D	330,000	Herbicide

1. Estimated applications are in pounds/year of active ingredient.

Source: Chesapeake Bay Program 1994a.

### Pesticide Applications by Major Chesapeake Bay Basins



**Figure 4.** Total pounds of herbicides (■), insecticides (▨), and fungicides (□) applied as active ingredient per year by major Chesapeake Bay basin. Source: Chesapeake Bay Program 1994a.

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

**Table 12.** Estimates of total herbicide, insecticide, and fungicide applications by major Chesapeake Bay basins<sup>1</sup>.

	Total Basinwide Application	Susq.	West Chesapeake	Patuxent	Potomac	Rapp.	York	James	Eastern Shore
Herbicides	9,271,711	2,113,319	963,375	154,948	2,186,993	474,554	442,862	522,620	2,413,040
Insecticides	2,617,231	175,027	137,301	110,289	817,986	303,202	246,273	425,713	401,440
Fungicides	1,282,862	175,599	28,706	21,574	632,224	99,141	15,358	229,532	80,728
<b>Total Pesticides</b>	<b>13,171,804</b>	<b>2,463,945</b>	<b>1,129,382</b>	<b>286,811</b>	<b>3,637,202</b>	<b>876,898</b>	<b>704,492</b>	<b>1,177,865</b>	<b>2,895,208</b>

1. Estimated applications are in pounds/year of active ingredient.

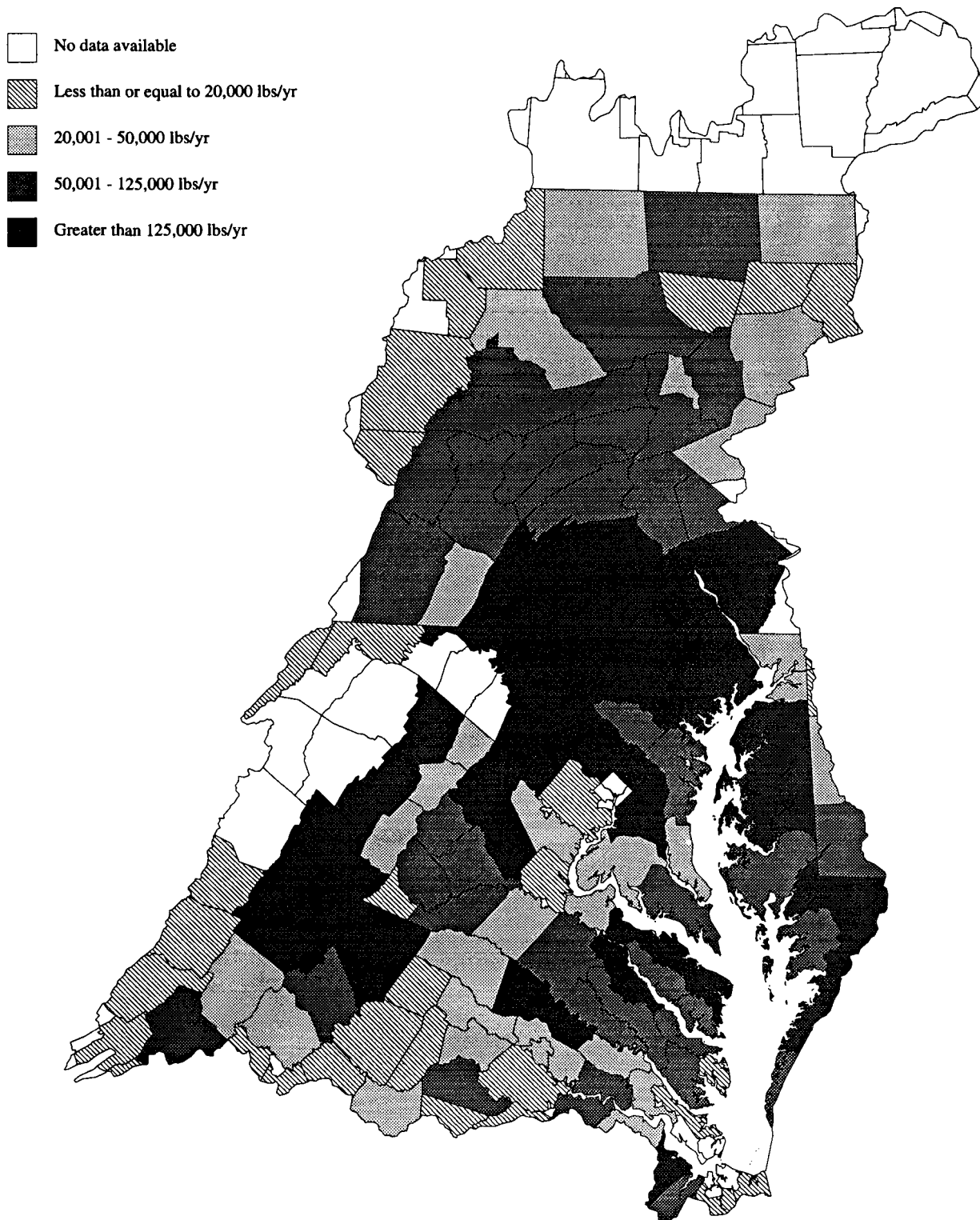
Source: Chesapeake Bay Program 1994a.

**Table 13.** Principal crops/use patterns and commonly applied pesticides within regions of Pennsylvania, Maryland, and Virginia.

State/Region (s)	Principal Crops/Use Patterns	Commonly Applied Herbicides	Commonly Applied Insecticides	Commonly Applied Fungicides	General Period of Heaviest Application
Pennsylvania—Southeast and Central Regions	Corn, alfalfa	Atrazine, alachlor, metolachlor, cyanazine, benefin, paraquat, simazine, profluralin, 2,4-D	Furandian, methamidothos, methoxychlor, parathion		First two weeks of May.
Pennsylvania—South Central and Southwest Regions	Fruit	Simazine, paraquat	Imidan, lannate, phosphamidon, parathion, methyuthion	Captan, maneb, sulfur	Early spring and throughout the summer.
Maryland—Eastern Shore	Corn, soybeans, vegetables	Atrazine, alachlor, metolachlor,	Carbofuran		First week of May.
Maryland—Central and Western Regions	Corn, alfalfa, soybeans, fruit, turf	Atrazine, alachlor, metolachlor, cyanazine, simazine, trifluralin, linuron, dicamba	Carbofuran, guthion, phosmet, methomyl	Mancozeb, zineb, metiram, captan, benomyl, fenarimol	First week of May; throughout growing season for fruit crops.
Maryland—Southern Region	Tobacco	Pendimethalin	Orthene		June.
Virginia—Northern Neck	Small grains, soybeans, corn	Paraquat, glyphosate, metolachlor, linuron, alachlor, 2,4-D	Carbofuran		Second week of June.
Virginia—Eastern Shore	Small grains, soybeans, potatoes	2,4-D, paraquat, trifluralin, metribuzin, senor			First week in March; last week in June.
Virginia—Shenandoah Valley	Corn, small grains, hay	2,4-D, paraquat, atrazine			First week in March; third week in May.
Virginia—South Central Region	Tobacco		Carbofuran, durisban, ethoprop, carbaryl, orthene		First week in June.
Pennsylvania, Maryland, and Virginia—Urban/Suburban Areas	Lawns, gardens, construction	2,4-D, dicamba, MCPP, benefin	Diazinon, malathion, carbaryl		Throughout the spring and summer.

Source: Roeser 1988.

## Pesticide Applications By Chesapeake Bay Basin County



**Figure 5.** Ranges of total pesticide applications by county within the Chesapeake Bay basin. Source: Chesapeake Bay Program 1994a.

## **INDUSTRIAL RELEASES**

Toxics Release Inventory data, collected as a requirement of the Emergency Planning and Community Right-to-Know Act (also known as Title III of the Superfund Amendments and Reauthorization Act of 1986 or SARA), is summarized here to provide a baseline of the industrial emissions of potentially toxic chemicals. Title III of SARA requires industries with more than ten employees which use more than 10,000 pounds of any one of more than 300 specific chemicals to report annually on the releases, discharges, and transfers of these chemicals to the land, air, or water. Title III of SARA also requires annual reports of shipments of these chemicals to off-site facilities which treat, store, or dispose of the wastes.

Releases of chemicals to air and land are not quantified in terms of the actual amounts reaching the Bay tidal waters. No models currently available quantify potential loadings to the Bay's tidal waters based on estimated releases within the Bay basin. The estimates of releases to surface waters provided here are not always based on measured values as are the estimates in the loadings section; therefore, the two estimates are not comparable.

Total reported releases and transfers from Chesapeake Bay basin Toxics Release Inventory reporting facilities declined 52 percent from 1987 to 1991 even as the number of industrial facilities reporting releases increased from 3,285 in 1987 to 3,924 by 1991 (Figure 6) [50]. Data from the Toxics Release Inventory indicate significant industrial releases of chemicals to media other than surface waters (e.g., air release, underground injection, land disposal) (Table 14).

Air releases represent the majority of chemical releases reported, accounting for 44 percent of the releases in 1987 and 68 percent in 1991 [50]. Although the percent of air contribution is increasing, the total amount released to the atmosphere declined 27 percent from 1987 to 1991.

Discharges to surface waters represented the smallest contribution, accounting for only 1.5 percent of the total reported releases and transfers for 1991. Off-site transfers to treatment, storage, and disposal facilities and municipal wastewater treatment plants accounted for 21 and 7 percent, respectively, of the reported 1991 total. Releases and transfers of all reported pollutants for these two categories are also decreasing.

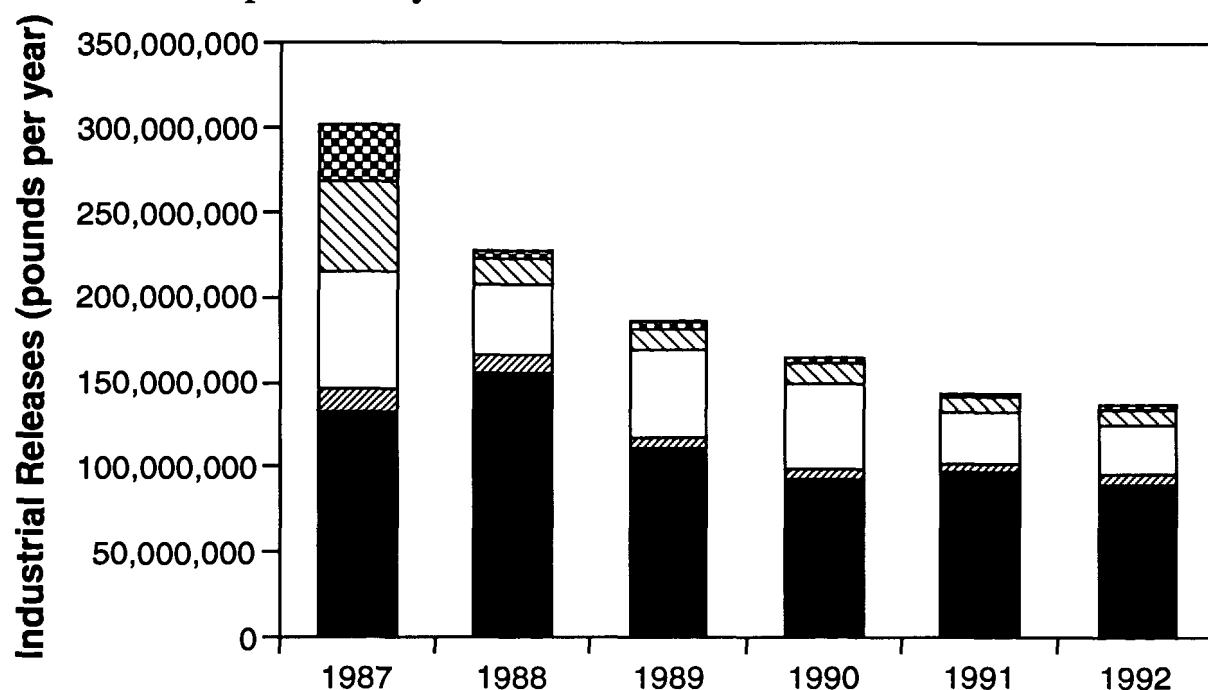
## **Transport Pathways to the Bay**

### **FALL LINE LOADINGS**

Fall line loading estimates provide a measure of the amount of chemical contaminants discharged or released from point and nonpoint sources (i.e., pesticide applications, atmospheric deposition to land and water surfaces) in the respective watershed areas above the fall line and delivered to the upper reaches of the Chesapeake Bay's tidal tributaries (i.e., Potomac, James) and the upper Bay mainstem in the case of the Susquehanna River. It is not possible, however, to subdivide total fall line loadings by specific contributing sources.

The Chesapeake Bay Fall Line Toxics Monitoring Program was established as a pilot study in April 1990 to define the magnitude and timing of chemicals entering the tidal Chesapeake Bay from point and nonpoint sources above the fall line of two major tributaries—the Susquehanna and James rivers [193]. The two fall line monitoring stations are located at the Conowingo Dam in Maryland for the Susquehanna River and Cartersville, Virginia for the James River. In 1992, the study was further expanded to include fall line monitoring on the Potomac River at Chain Bridge in Virginia in addition to the monitoring conducted in the Susquehanna and James rivers (Figure 7) [194, 195]. Base flow samples were collected biweekly and storm event sampling was conducted throughout the year. Combined, these three rivers provide approximately 80 percent of the total freshwater coming into the Chesapeake Bay. Loading estimates

## Chesapeake Bay Basin Industrial Releases of Chemicals



**Figure 6.** Chesapeake Bay basin industrial releases and transfers of chemicals to water (i.e. receiving stream) (▣), publicly owned treatment works (▤), off-site for treatment and/or disposal (□), landfill disposal (▥), and air through stack or fugitive emissions (■). Source: Chesapeake Bay Program, 1994a; U.S. Environmental Protection Agency 1993c.

**Table 14.** Releases and transfers of chemicals from Chesapeake Bay basin Toxics Release Inventory facilities.<sup>1</sup>

Year	Direct Releases to Water (Receiving streams)	Transfers Off-site to Publicly Owned Treatment Works	Transfers off-site for Disposal and/or Treatment	Landfill Disposal	Releases to Air Through and Not Through Confined Air Systems
1987	33,630,000	53,160,000	69,410,000	13,420,000	132,660,000
1988	3,640,000	16,010,000	40,520,000	10,950,000	154,860,000
1989	4,170,000	13,230,000	50,580,000	6,020,000	112,490,000
1990	3,320,000	11,770,000	50,060,000	5,570,000	93,380,000
1991	2,140,000	9,790,000	30,100,000	4,580,000	97,290,000
1992	2,330,000	9,780,000	28,950,000	5,640,000	90,410,000

1. Releases and transfers, given in pounds/year, have been rounded to four significant figure for presentation purposes.

Sources: Chesapeake Bay Program 1994a, U.S. Environmental Protection Agency, 1993c.



were calculated using either discharge-weighted concentrations and annual flow or a numerical model developed by Cohn [58].

Large fall line loadings of the seven Toxics of Concern/Secondary List metals were estimated for all three basins, with the highest reported loads at the Susquehanna, followed by the James and Potomac (Table 15). Estimated fall line loadings of zinc were the highest followed by copper and lead.

The differences in fall line loadings of Toxics of Concern polycyclic aromatic hydrocarbons were minimal among the Susquehanna, James, and Potomac fall lines, with combined fall line loadings of benzo[*a*]anthracene, benzo[*a*]pyrene, fluoranthene, and naphthalene ranging from 147 to 442 pounds per year (Table 15).

The Susquehanna had the highest reported fall line loadings of pesticides, followed by the Potomac and James (Table 15). Estimated fall line loadings for atrazine, cyanazine, metolachlor, and simazine were significantly higher than the other pesticides monitored—aldrin, alachlor, chlordane, DDT, dieldrin, fenvalerate, hexachlorocyclopentadiene, malathion, permethrin, and prometon—at both the Susquehanna and Potomac fall lines [193, 194, 195] (Figure 8).

## GROUNDWATER

It was not possible to develop chemical contaminant loading estimates for groundwater using existing data. To address this concern, a critical issue forum was held to assess the significance of chemical contaminant loads from groundwater into the Chesapeake Bay and to develop a strategy for quantifying these loads (Figure 9) [47].

The mean annual freshwater flow entering the Chesapeake Bay is approximately 18.9 million gallons (at a rate of 600,000 gallons per second) [238]. More than one-half of this fresh water is delivered by groundwater discharged through shallow aquifers as base flow to tidal and

nontidal tributaries or upwelled as direct discharge to the Bay. Sinnott and Cushing [281] estimated that approximately 55 percent of the streamflow below the fall line and 40 percent of the streamflow above the fall line is groundwater discharging as base flow. Other estimates of base flow represented as a total percentage of streamflow in the Chesapeake Bay watershed range from 39 to 61 percent [7, 47, 64, 175, 276, 344].

Excluding local contamination data at hazardous waste sites, there are very limited data on chemical contaminant concentrations in groundwater within the Bay watershed. The available data are primarily for pesticides, with atrazine and alachlor being the two most commonly detected pesticides. On the Delmarva Peninsula, concentrations of pesticides were generally low; 94 percent of the water samples with detectable concentrations were less than the U.S. Environmental Protection Agency (EPA) maximum contaminant and health advisory levels for drinking water [130]. Similar results were found at the Nomini Creek watershed within the Potomac River basin; over 21 pesticides were detected in the ground water, but only atrazine, disulfoton, and paraquat occasionally exceeded their respective drinking water standards [204]. In the groundwater underlying the Owl Creek watershed in Rappahannock River basin, no pesticides have been detected [204]. Triazine pesticides were detected, however, in 42 of 50 wells sampled in the Cumberland Valley of Pennsylvania—above the fall line in the Susquehanna River basin [153].

The primary conclusions from the critical issue forum were that although measurable concentrations of pesticides have been detected in shallow aquifers, surface runoff is a significantly larger source of pesticides to streams and tributaries than groundwater [47]. Any potential for groundwater to be a loading source of chemicals is greatest at the local scale, close to the original source of contamination.

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

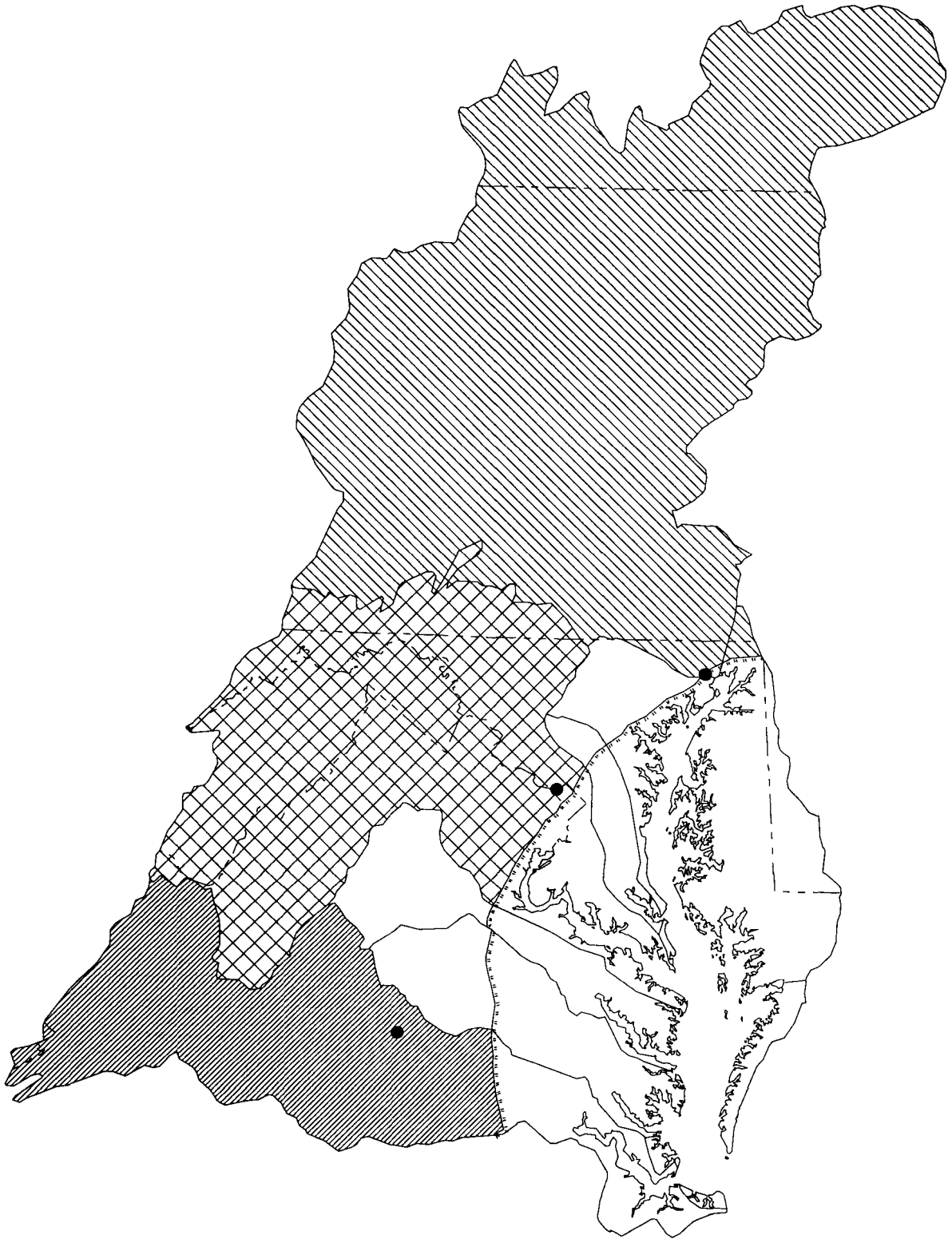
**Table 15.** Estimates of fall line loads of Chesapeake Bay Toxics of Concern and Secondary List chemicals by major Chesapeake Bay basins<sup>1</sup>.

Chemical Category/ Chemical	Total Basinwide Loading	Susq.	West Chesapeake	Patuxent	Potomac	Rapp.	York	James	Eastern Shore
<b>METALS</b>									
Arsenic	139,064	63,917	NE <sup>2</sup>	NE	63,839	NE	NE	11,308	NE
Cadmium	71,363	41,888	NE	NE	20,587	NE	NE	8,888	NE
Chromium	430,550	254,958	NE	NE	88,934	NE	NE	86,658	NE
Copper	451,453	247,126	NE	NE	114,127	NE	NE	90,200	NE
Lead	341,235	127,398	NE	NE	129,962	NE	NE	83,875	NE
Mercury	6,653	5,918	NE	NE	NE	NE	NE	735	NE
Zinc	2,110,961	1,185,800	NE	NE	625,081	NE	NE	300,080	NE
<b>PAHs</b>									
Benzo[a]anthracene	320	168	NE	NE	85	NE	NE	67	NE
Benzo[a]pyrene	370	147	NE	NE	66	NE	NE	157	NE
Fluoranthene	651	297	NE	NE	46	NE	NE	308	NE
Naphthalene	972	660	NE	NE	165	NE	NE	147	NE
<b>PESTICIDES</b>									
Alachlor	406	283	NE	NE	76	NE	NE	47	NE
Aldrin	58	41	NE	NE	10	NE	NE	7	NE
Atrazine	5,940	3,740	NE	NE	1,716	NE	NE	484	NE
Chlordane	317	149	NE	NE	79	NE	NE	89	NE
Dieldrin	65	23	NE	NE	33	NE	NE	9	NE
Metolachlor	3,081	2,024	NE	NE	858	NE	NE	199	NE

1. Estimated mean annual loadings in pounds/year.
2. Fall line loadings were not measured and, therefore, not estimated.

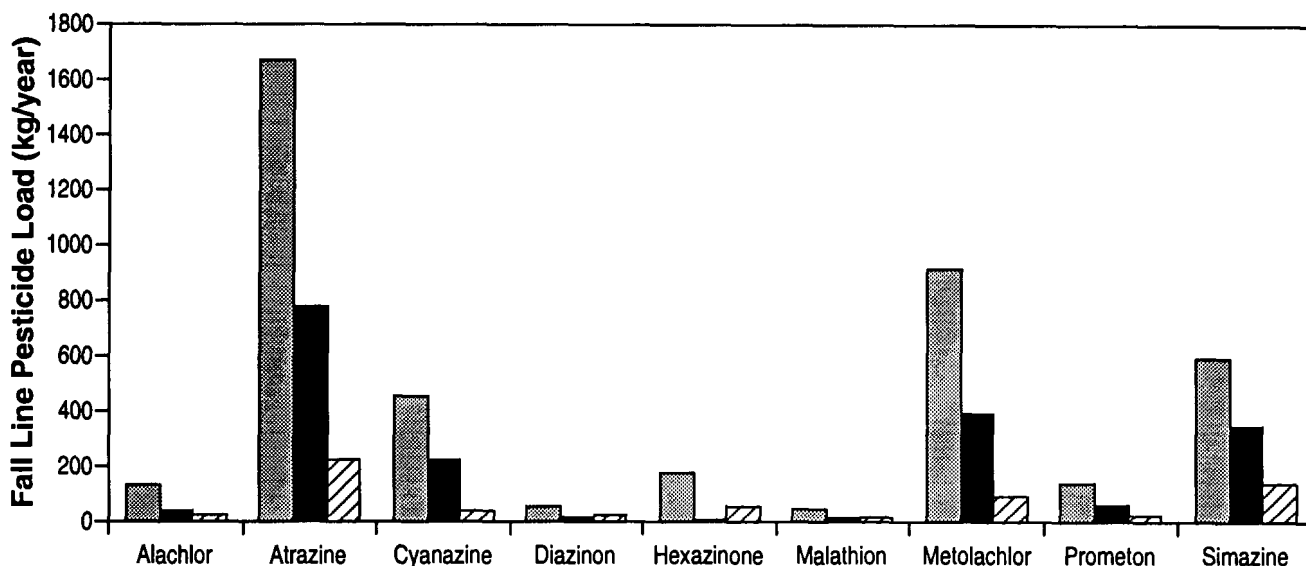
Sources: Maryland Department of the Environment and Metropolitan Washington Council of Governments 1994a, 1994b.

## Chesapeake Bay Fall Line Toxics Monitoring Stations



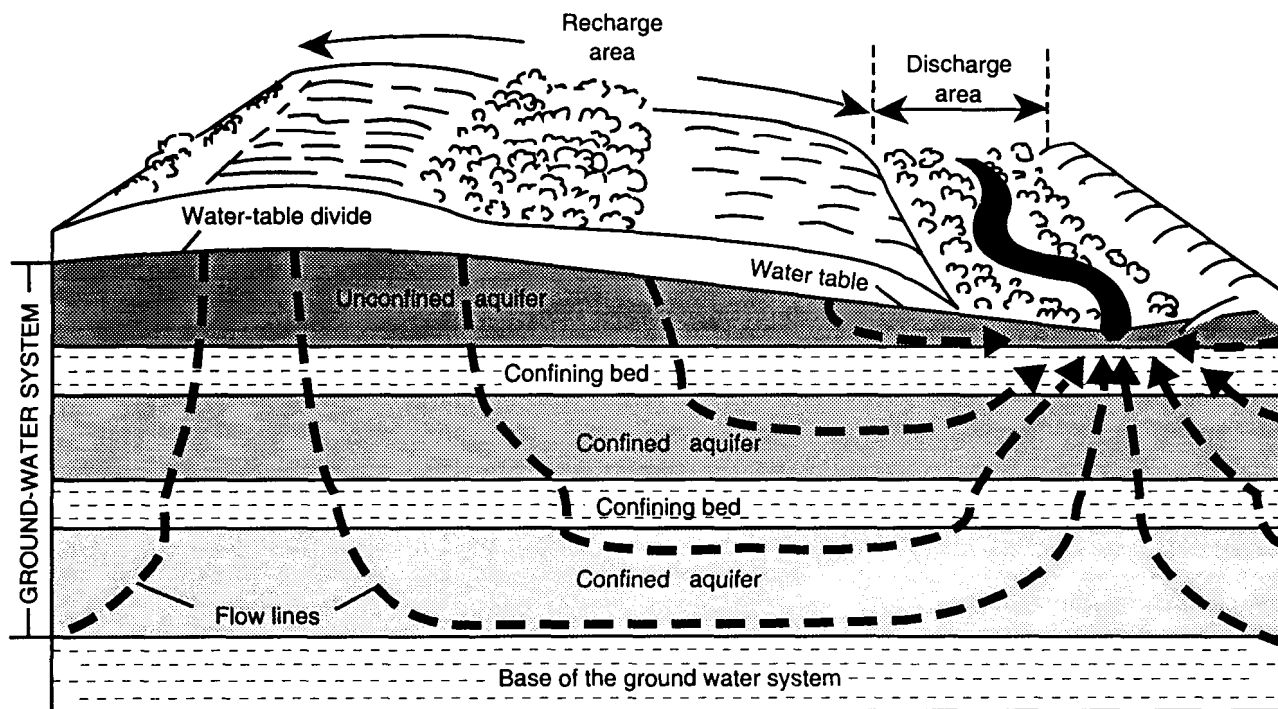
**Figure 7.** Locations of the Susquehanna, Potomac, and James rivers fall line toxics monitoring stations (●). Sources: Maryland Department of the Environment and Metropolitan Washington Council of Governments 1994a.

## Chesapeake Bay Fall Line Pesticide Loadings



**Figure 8.** Estimated loadings of selected pesticides at the Susquehanna (▨), Potomac (■), and James (▨) fall lines over the period March 1992 – February 1993. Mean annual loadings are the sum of the dissolved and particle fractions. Sources: Maryland Department of the Environment, and Metropolitan Washington Council of Governments 1994a, 1994b.

## Groundwater: Potential Routes of Chemical Loadings



**Figure 9.** Illustration of the potential routes of chemical loadings to groundwater. Water that enters a ground-water system in recharge areas moves through the aquifers and confining beds comprising the system to discharge areas (i.e., Bay tributaries). Source: Adapted from Phillips, Personal Communication.

## **Below Fall Line Loadings**

### ***POINT SOURCE DISCHARGES - BELOW FALL LINE***

Estimated loadings presented in this section come from those point source facilities which discharge directly to waters below the fall line (Figure 2). See pages 9-10 for a more complete discussion of point sources and load estimations.

Most below fall line point source loadings of Toxics of Concern\ Secondary List metals come from the West Chesapeake, Potomac, and James basins (Table 16). Metals loadings of less than 6,300 pounds per year were reported below the fall line in the Eastern Shore basin with 50 pounds per year reported for the Patuxent basin; no estimated loadings were reported for the Rappahannock and York basins in the inventory. The highest individual Toxics of Concern/Secondary List metals loadings were for zinc, followed by copper, chromium, and lead (Table 16). Loadings of Toxics of Concern polycyclic aromatic hydrocarbons were generally 100 pounds per year or less, with no estimated loadings reported for the inventoried facilities in the Patuxent, Potomac, Rappahannock, York, and Eastern Shore basins (Table 16).

### ***URBAN STORMWATER RUNOFF - BELOW FALL LINE***

Large loadings of seven Toxics of Concern/ Secondary List metal loadings from urban stormwater runoff to below fall line surface waters were estimated across the major Chesapeake Bay basins, with individual metals generally varying several orders of magnitude between individual basins (Table 17). The highest basinwide metal loadings were for zinc, followed by copper, chromium, lead, arsenic, cadmium, and mercury. The highest metal loads were estimated for the West Chesapeake followed by the Potomac, James, Eastern Shore, Patuxent, York, and Rappahannock basins.

Estimated loadings of the five polycyclic aromatic hydrocarbons on the Toxics of Concern List ranged from 200 to 1,000 pounds per year basinwide (Table 17). The highest estimated loads of all five compounds combined were estimated for the West Chesapeake followed by the Potomac, James, Eastern Shore, York, Patuxent, and Rappahannock basins.

Total estimated urban stormwater runoff loadings of chemical contaminants presented by county clearly illustrate that the counties with the highest estimated loadings tend to be concentrated at or below the fall line and in the lower Susquehanna basin (Figure 10). This pattern is particularly noticeable in the region surrounding the upper tidal Potomac and Maryland's upper western shore.

### ***ATMOSPHERIC DEPOSITION TO TIDAL WATERS***

Atmospheric deposition is the gross transport of chemicals from the atmosphere to both land and water surfaces. The magnitude of atmospheric deposition is proportional to the concentration of the chemical in the atmosphere and is dependent upon both the emission rate into the atmosphere and a variety of atmospheric transport and reaction processes.

Atmospheric deposition results both from wet and dry depositional processes. Wet deposition includes washout of atmospheric particles (aerosols) by precipitation, as well as washout of gaseous chemicals via dissolution into raindrops. The magnitude of wet deposition depends directly upon the intensity and duration of the precipitation event, the concentrations of aerosol-bound and gas phase chemicals in the atmosphere, and the efficiency with which the precipitation scavenges these chemicals. Wet depositional fluxes may be directly determined at a site by collecting precipitation and analyzing the chemicals of interest.

**Table 16.** Estimates of below fall line point source loads for Chesapeake Bay Toxics of Concern and Secondary List chemicals by major Chesapeake Bay basin<sup>1</sup>.

Chemical Category/ Chemical	Total BFL <sup>2</sup> Basinwide Loading	West Ches.	Patuxent	Potomac	Rapp.	York	James	Eastern Shore
<b>Metals</b>								
Arsenic	1,375	825	50	–	–	–	475	25
Cadmium	1,330	1,116	–	155	–	–	31	31
Chromium	43,680	35,840	–	2,800	–	–	4,480	–
Copper	82,800	39,600	–	27,600	–	–	14,400	1,200
Lead	12,650	7,130	–	3,220	–	–	2,300	230
Mercury	510	412	–	75	–	–	23	–
Zinc	364,800	206,400	–	100,800	–	–	48,000	4,800
<b>PAHs</b>								
Benzo[a]pyrene	100	22	–	–	–	–	78	–
Chrysene	20	–	–	–	–	–	20	–
Fluoranthene	50	–	–	–	–	–	50	–
Naphthalene	1,400	1,400	–	–	–	–	–	–

1. Estimated loadings are in pounds/year.
2. Below fall line.
3. "–" indicates no loadings were estimated within the Inventory.

Sources: Chesapeake Bay Program 1994a, 1994b.

Dry deposition results from the transport of aerosols to the land or water surface and the absorption of gaseous chemicals into vegetation, soils, and surface waters. While it is generally accepted that dry aerosol depositional fluxes are proportional to the concentrations of aerosol-bound chemicals in the atmosphere, direct field measurements of dry deposition provide only order-of-magnitude ranges of flux estimates at best.

Atmospheric loading estimates for metals, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls (PCBs) are based on results

from the Chesapeake Bay Atmospheric Deposition Study conducted in 1990 and 1991 [11, 45, 70]. Atmospheric loading estimates for pesticides are based solely on bulk precipitation samples collected between 1977 and 1984 and reported in the literature [92, 335, 340]. In these pesticide studies, open collectors were deployed for extended periods adjacent to agricultural fields. While these studies provide some important first measurements of pesticide atmospheric deposition rates, the close proximity of the samples to agricultural areas likely resulted in overestimates of the true regional depositional fluxes [11].

**Table 17.** Estimates of below fall line urban stormwater runoff loads of Chesapeake Bay Toxics of Concern and Secondary List chemicals by major Chesapeake Bay basins<sup>1</sup>.

Chemical Category/ Toxic Substance	Total BFL <sup>2</sup> Basinwide Loading	West Ches.	Patuxent	Potomac	Rapp.	York	James	Eastern Shore
<b>Metals</b>								
Arsenic	25,080	9,120	1,710	5,700	570	1,710	3,990	2,280
Cadmium	6,160	2,240	420	1,400	140	420	980	560
Chromium	36,080	13,120	2,460	8,200	820	2,460	5,740	3,280
Copper	101,200	36,800	6,900	23,000	2,300	6,900	16,100	9,200
Lead	21,560	7,840	1,470	4,900	490	1,470	3,430	1,960
Mercury	1,144	416	78	260	26	78	182	104
Zinc	572,000	208,000	39,000	130,000	13,000	39,000	91,000	52,000
<b>PAHs</b>								
Benzo[a]pyrene	208	108	8	48	–	12	20	12
Benzo[a]anthracene	192	100	7	44	–	11	19	11
Chrysene	520	270	20	120	–	30	50	30
Fluoranthene	780	405	30	180	–	45	75	45
Naphthalene	988	513	38	228	–	57	95	57

1. Estimated loads are in pounds/year.
2. Below fall line.
3. "–" indicates no loadings were estimated within the Inventory.

Source: Chesapeake Bay Program 1994a.

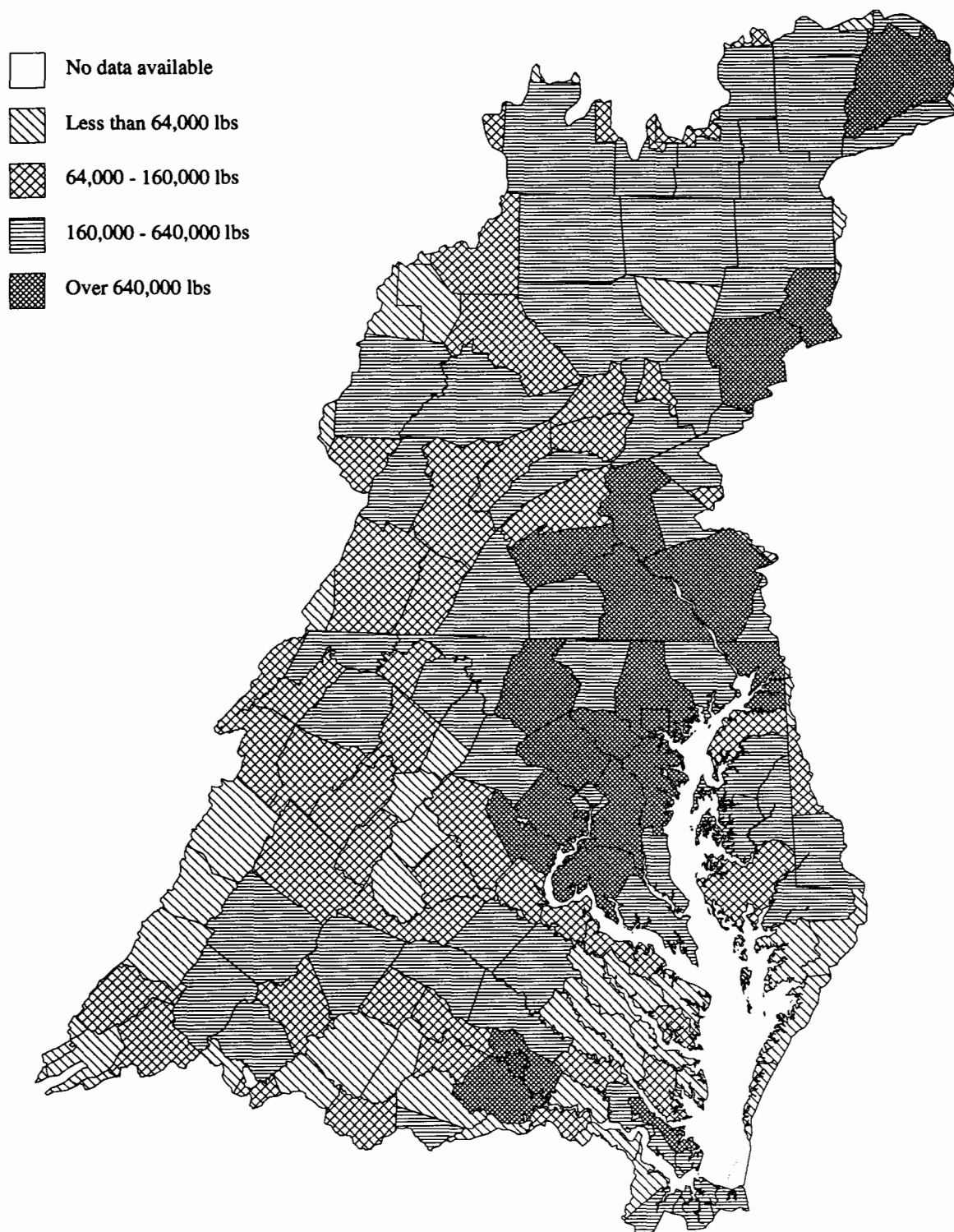
These atmospheric deposition loadings include only wet and dry atmospheric deposition to surface waters of the Bay's mainstem and tidal tributaries and do not include atmospheric deposition to non-tidal surface waters above the fall line or land areas above or below the fall line. The loading estimates were allocated to the individual basins based on tidal surface water area.

Zinc (91,000 pounds per year) had the highest estimated atmospheric deposition loadings direct to tidal waters of all the Toxics of Concern/Secondary List metals, followed by lead (32,000 pounds per year) and copper (24,000 pounds per

year) (Table 18). Based on total tidal surface water area, the mainstem Bay had the highest atmospheric deposition metal loadings followed by the Potomac, James, Eastern Shore, West Chesapeake, Rappahannock, Patuxent, and York basins. Total estimated atmospheric deposition loadings of the Toxics of Concern polycyclic aromatic hydrocarbons ranged from 280 pounds per year for benzo[a]pyrene to 1,400 pounds per year for fluoranthene with total annual loading of total PCBs of 130 pounds per year (Table 18).

The pesticides with the largest total estimated atmospheric loadings are alachlor (5,600 pounds

### Urban Storm Water Runoff Chemical Loadings by Chesapeake Bay Basin County



**Figure 10.** Ranges of total urban runoff loadings of chemicals by county within the Chesapeake Bay basin. Source: Chesapeake Bay Program 1994a.



per year), malathion (3,500 pounds per year), metolachlor (2,700 pounds per year), toxaphene (1,800 pounds per year), and atrazine (1,700 pounds per year) (Table 18). An estimated 17,600 pounds per year of 13 pesticides are deposited directly to Bay tidal surface waters from the atmosphere [50].

The sample collection stations are located in rural areas—a limitation of these atmospheric deposition loading estimates which may result in under-estimating the total loadings. No urban stations were part of the network when these estimates were made. A study in the early 1980s in the southern Chesapeake Bay indicated that substantially higher total hydrocarbon fluxes occurred at an urban station (Norfolk, Virginia) compared to more rural stations [309, 315]. Work is underway to establish atmospheric deposition stations around the Baltimore region to address this need [8].

Concentrations of polycyclic aromatic hydrocarbons in the air over Chesapeake Bay are within the same order-of-magnitude as those measured over the Great Lakes, Sweden's coast, and the Baltic Sea (Table 19). Concentrations of polycyclic aromatic hydrocarbons measured around urbanized areas (including Baltimore, Maryland) are an order-of-magnitude higher than average baywide polycyclic aromatic hydrocarbon concentrations. Total PCB concentrations in the atmosphere over Chesapeake Bay were very similar to those measured for Lake Ontario and at remote locations, but almost four times lower than those reported for Lake Superior (Table 20) [11]. Estimates of total wet and dry atmospheric deposition fluxes to Chesapeake Bay of selected metals tend to be slightly lower (although higher in the case of polycyclic aromatic hydrocarbons) than those measured over the Great Lakes (Table 21).

## ***SHORELINE EROSION***

In many areas of the Bay, shoreline erosion provides a significant quantity of sediment to the tidal waters [26, 272]. This erosion can be an important source of trace metals and other sediment-associated chemical contaminants to the Bay. Velinsky [306] has made estimates of erosion-based loadings of metals and organic compounds (Figure 11). Based on data reported by Helz et al. [148], average mass erosion rates and metal concentrations for various sections of the Maryland Bay were used to derive metal loadings due to sediment erosion. Estimates of metal loads from the Virginia portion of the Bay were based on sediment erosion data reported by Byrne and Anderson [36].

## ***HOUSEHOLD HAZARDOUS WASTES***

Currently, no estimates exist for chemical contaminant loadings from improper disposal of household hazardous wastes to portions of the Bay watershed below the fall line.

## ***AGRICULTURAL PESTICIDE WASTES***

There are no estimates of the loading of pesticides to the below fall line portion of the Bay basin from the storage of unusable, cancelled, or banned pesticides.

## ***COMMERCIAL SHIPPING AND TRANSPORT***

The Chesapeake Bay is a major center for shipping commerce, commercial and recreational fishing, and general boating activities. The chemicals from these activities which have the highest potential for release to surface waters are oils and other petroleum products, chemicals to treat human waste, cleaning fluids, antifreeze, and antifouling paints [50].

**Table 18.** Estimates of atmospheric deposition direct to tidal surface waters loads of Chesapeake Bay Toxic of Concerns and Secondary List chemicals by major Chesapeake Bay basin<sup>1</sup>.

Chemical Category/ Chemical	Total BFL Basinwide Loading	Mainstem Bay	West Ches.	Patuxent	Potomac	Rapp.	York	James	Eastern Shore
<b>Metals</b>									
Arsenic	3,800	2,470	152	76	418	152	76	228	228
Cadmium	2,700	1,755	108	54	297	108	54	162	162
Chromium	7,500	4,875	300	150	825	300	150	450	450
Copper	24,000	15,600	960	480	2,640	960	480	1,440	1,440
Lead	32,000	20,000	1,280	640	3,520	1,280	640	1,920	1,920
Zinc	91,000	59,150	3,640	1,820	10,010	3,640	1,820	5,460	5,460
<b>PAHs</b>									
Benzo[a]anthracene	300	195	12	6	33	12	6	18	18
Benzo[a]pyrene	280	182	11	6	31	11	6	17	17
Chrysene	710	462	28	14	78	28	14	43	43
Fluoranthene	1,400	910	56	28	154	56	28	84	84
<b>PCBs</b>									
PCBs (Total)	130	84	5	3	14	5	3	8	8
<b>Pesticides</b>									
Alachlor	5,600	3,640	224	112	616	224	112	336	336
Atrazine	1,700	1,105	68	34	187	68	34	102	102
Chlordane	170	11	7	3	19	7	3	10	10
Metolachlor	2,700	1,755	108	54	297	108	54	162	162
Toxaphene	1,800	1,170	72	36	198	72	36	108	108

1. Estimated loadings are in pounds/year.

Source: Chesapeake Bay Program 1994a.

Oil and other petroleum products have the potential for causing pollution in the Bay because virtually every vessel carries them on board as fuel; tankers and barges also transport large volumes as cargo. For example, of the 37,500,000 tons of total cargo handled in Baltimore during 1987, approximately 4,700,000 tons were petroleum products. Because of the volume of petroleum products transported through shipping, the initial *Basinwide Toxics Loading and Release Inventory* focused on oil and other petroleum products in estimating chemical contaminant loads from shipping. From 1980 to 1989, 3,200 spills released approximately 2,700,000 gallons of

petroleum products within the Chesapeake Bay coastal zone [50]. Very limited spill data, however, were reported for Toxics of Concern/Secondary List chemicals.

### **RECREATIONAL/COMMERCIAL BOATING**

Non-transport activities, such as commercial and recreational fishing and boating, can also result in chemical loadings to the Bay. More than 180,000 recreational and commercial fishing boats are registered in the Maryland portion of the Chesapeake Bay alone. The daily operation and

**Table 19.** Comparison of Chesapeake Bay and worldwide polycyclic aromatic hydrocarbon concentrations in air<sup>1</sup>.

Polycyclic Aromatic Hydrocarbon	Chesapeake Bay <sup>2</sup>	Lake Superior <sup>3</sup>	Denver Colorado <sup>4</sup>	Niagra River <sup>5</sup>	Portland Oregon <sup>6</sup>	Baltimore Maryland <sup>7</sup>	Stockholm Sweden <sup>8</sup>	Baltic Sea <sup>9</sup>	Mediterranean Sea <sup>9</sup>
Anthracene	50	—	3,200	1,000	2,800	2,900	120	20	3.7
Benzo[a]anthracene	40	130	—	2,800 <sup>11</sup>	1,500	7,600	160	30	4.8
Benzo[a]pyrene	34	5	1,700	230 <sup>11</sup>	1,200 <sup>11</sup>	5,800	160	140	6.2
Benzo[b]fluoranthene	101	23	—	—	3,500	10,600	—	—	—
Benzo[e]pyrene	65	6.3	—	420 <sup>11</sup>	1,200	5,000	420	70	22
Benzo[ghi]perylene	64	13	4,200	530 <sup>11</sup>	2,000 <sup>11</sup>	8,000	640	70	9.1
Benzo[k]fluoranthene	58	20	830	1,100	—	10,600	480	110	—
Chrysene	97	6.3 <sup>10</sup>	—	3,900 <sup>11</sup>	1,800	12,000 <sup>10</sup>	780 <sup>10</sup>	110 <sup>10</sup>	35 <sup>10</sup>
Dibenz[a,h]anthracene	9	—	4,200	—	—	—	—	—	—
Fluoranthene	405	180	12,600	5,100	8,300	20,000	1,700	340	30
Fluorene	570	450	—	—	6,100	—	—	—	—
Indeno[1,2,3-cd]pyrene	58	18	3,600	—	—	4,600	410	110	6
Phenanthrene	1,780	2,600	38,000	13,800	27,000 <sup>11</sup>	1,800	2,560	740	26
Pyrene	480	340	21,200	4,200	7,500	27,000	1,370	180	24

1. Sum of particulate and aerosol phases; concentrations pg/m<sup>3</sup>.
2. Baker et al. 1992, 1994a; Dickhut et al. 1992; Leister and Baker 1993; Scudlark et al. 1993.
3. Baker and Eisenreich 1990.
4. Foreman and Bidleman 1990.
5. Hoff and Chan 1987.
6. Ligocki et al. 1985a, 1985b.
7. Benner et al. 1989.
8. Broman et al. 1991.
9. Simon et al. 1991.
10. Chrysene and triphenylene.
11. Aerosol phase only.

Source: Baker et al. 1994a.

Estimated fall line loadings from the non-tidal reaches of the Bay's three major basins—the Susquehanna, Potomac, and James—were a very minor “source” of organic chemical contaminants to Bay tidal waters compared to other inventoried sources. These loadings are evidence of loads to non-tidal tributaries being diminished by chemical and physical degradation enroute to the fall line.

## PESTICIDES

Estimates of pesticide loadings could be made for only two inventoried sources from the available data. Loadings direct to tidal waters from atmospheric deposition were an order of magnitude higher than fall line loadings combined for the Susquehanna, Potomac, and James rivers (Table 25). The atmospheric deposition loading may be an overestimate and the fall line loading does not

account for the remaining 20 percent of the freshwater flow into the Bay. Atmospheric deposition, however, results in widespread distribution of pesticide loadings whereas the fall line source contributes loadings only to tidal areas immediately downstream of the fall line (Figure 14).

The highest total pesticide applications were reported for the Potomac basin, followed by the Eastern Shore, Susquehanna, James, West Chesapeake, Rappahannock, York, and Patuxent basins. Herbicides accounted for 70 percent of the total usage of pesticides reported basinwide followed by insecticides (20 percent) and fungicides (10 percent). In the Susquehanna, Potomac, and James basins, the estimated fall line loadings of pesticides were less than one tenth of a percent of the estimated total annual pesticides applied in the upland, non-tidal watershed.

**Table 23.** Basinwide comparisons of Toxics of Concern/Secondary List metal, organic compound, and pesticide loadings by source category.

Class of Toxic Substances	Point Sources		Urban Stormwater Runoff		Atmos. Dep. <sup>3</sup>	Shipping and Transport	Fall Line
	AFL <sup>1</sup>	BFL <sup>2</sup>	AFL	BFL			
Metals	○	●	●	●	○	—	●
Organics	—	●	●	●	●	○	●
Pesticides	○	—	—	—	●	—	●

Key:

	<u>Metals</u>	<u>Organics</u>	<u>Pesticides</u>
● = High range of loadings/releases:	>1,000,000	>2,000	>5,000
● = Medium range of estimated loadings/releases:	500,000-1,000,000	1,000-2,000	1,000-5,000
○ = Low range of estimated loadings/releases:	1-500,000	1-1,000	1-1,000
— = No estimated loading/release.			

Notes:

1. Above fall line.
2. Below fall line.
3. Atmospheric deposition to Chesapeake Bay tidal surface waters only.

Sources: Chesapeake Bay Program 1994a, 1994b.

**Table 24.** Comparisons of Chesapeake Bay basin Toxics of Concern/Secondary List organic compound loadings by source category.

BASIN	Point Sources		Urban Stormwater Runoff		Atmos. Dep. <sup>3</sup>	Shipping and Transport	Fall Line
	AFL <sup>1</sup>	BFL <sup>2</sup>	AFL	BFL			
Susquehanna	–	–	●	–	NA	–	●
W. Chesapeake	–	●	–	●	○	–	–
Patuxent	–	○	○	○	○	–	–
Potomac	–	○	●	●	●	–	○
Rappahannock	–	–	–	–	○	–	–
York	–	–	○	○	○	–	–
James	–	○	○	●	○	–	●
Eastern Shore	NA	–	NA	○	○	–	–
Mainstem	NA	NA	NA	NA	●	●	NA

**Key:**

- = High range of estimated loadings: >500 pounds/year.
- = Medium range of estimated loadings: 250 - 500 pounds/year.
- = Low range of estimated loadings: 1 - <250 pounds/year.
- = No estimated loading.
- NA = Not applicable.

**Notes:**

1. Above fall line.
2. Below fall line.
3. Atmospheric deposition to Chesapeake Bay tidal surface waters only.

Sources: Chesapeake Bay Program 1994a, 1994b.

Although concentrations of pesticides have been detected in shallow aquifers, surface runoff is a larger source of pesticides to streams and tributaries than groundwater. Any potential for

groundwater to be a loading source of pesticides is greatest at the local scale, close to the original source of contamination.

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

**Table 25.** Comparisons of Chesapeake Bay basin Toxics of Concern/Secondary List pesticide loadings by source category.

BASIN	Point Sources		Urban Stormwater Runoff		Atmos. Dep. <sup>3</sup>	Shipping and Transport	Fall Line
	AFL <sup>1</sup>	BFL <sup>2</sup>	AFL	BFL			
Susquehanna	–	–	–	–	NA	–	●
W. Chesapeake	–	–	–	–	○	–	–
Patuxent	–	–	–	–	○	–	–
Potomac	–	–	–	–	●	–	●
Rappahannock	–	–	–	–	○	–	–
York	–	–	–	–	○	–	–
James	○	–	–	–	●	–	○
Eastern Shore	NA	–	–	–	●	–	–
Mainstem	NA	NA	NA	NA	●	–	NA

## Key:

- = High range of estimated loadings: >1,000 pounds/year.
- = Medium range of estimated loadings: 500 - 1,000 pounds/year.
- = Low range of estimated loadings: 1 - <500 pounds/year.
- = No estimated loading.
- NA = Not applicable.

## Notes:

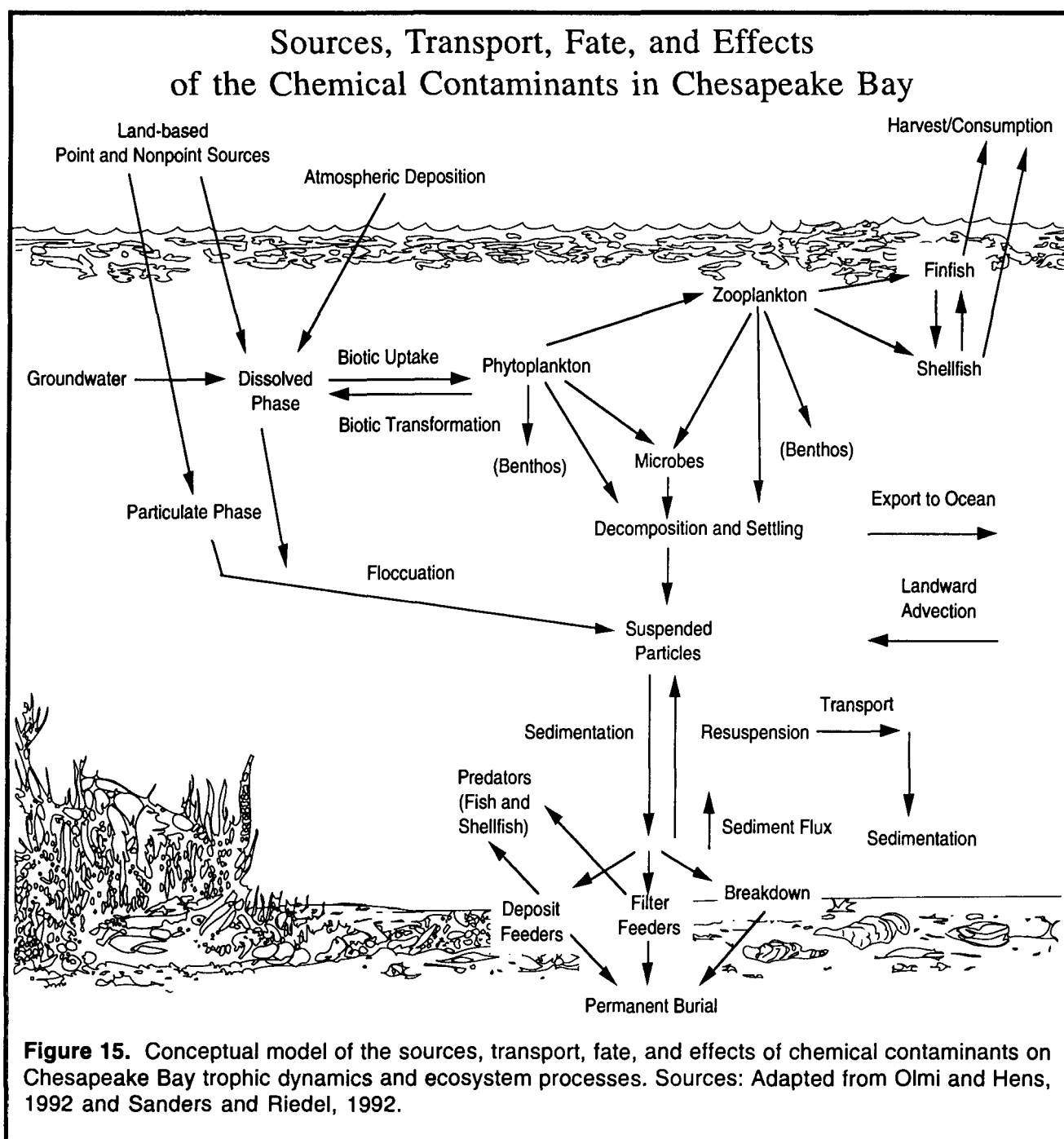
1. Above fall line.
2. Below fall line.
3. Atmospheric deposition to Chesapeake Bay tidal surface waters only.

Sources: Chesapeake Bay Program 1994a, 1994b.

## Transport and Fate of Bay Toxics

Since 1991, the National Oceanic and Atmospheric Administration's Chesapeake Bay Environmental Effects Committee and the Chesapeake Bay Program's Toxics Subcommittee have jointly funded a competitively-based research program to investigate the effects of potentially

toxic chemicals in Chesapeake Bay [162, 184, 185, 186, 187, 223]. This ecosystem-based program promotes the understanding of how Bay ecosystem processes influence the transport and fate of chemical contaminants, and conversely, the effect that representative classes of chemical contaminants have upon the ecological processes of the Bay (Figure 15). To date, this program has funded studies related to the particle-reactive behavior of chemical contaminants, sediment



transport, sediment diagenesis, and the role of pelagic and benthic communities in the fate and transport of chemical contaminants. The research program is shifting towards examining the effects of low-level concentrations of chemical contaminants on the Bay's living resources.

## **Air-Water Fluxes**

Chemical transfer across the air/water interface is a dominant process controlling concentrations and residence times of organic chemical contaminants to the Chesapeake Bay. To evaluate the importance of the atmosphere as a source of chemicals to the Bay, it is first necessary to know the quantities, types, and forms of chemicals present in the atmosphere, and second, to understand the processes which control compound partitioning at the air/water interface. Depositional studies of trace elements and hydrophobic organic chemicals have been conducted [11, 14, 70]. Through the toxics research program, Dickhut and colleagues [71] have been examining partitioning processes with measurement of the processes that control the transfer of selected organic chemicals from air to water under a variety of environmental conditions. Such work has yielded a mechanism to accurately predict air/water partitioning and mass transfer properties and the availability of these organic compounds [97].

## **Transport and Availability in the Water Column**

Biological processes can play an important but variable role in the transport of chemical contaminants to sediments. Sanders and Sellner [261] have examined the potential for algal blooms to transport significant quantities of chemical contaminants to sediments and have found that the quantity of chemical contaminants settling through the water column varies among different systems and with different algal species. Baker and colleagues [15] have determined that hydro-

phobic organic chemicals associated with particles in the Bay vary both seasonally and with particle size, with generally higher hydrophobic organic concentrations in zooplankton-sized particles. These processes have a major impact on the fate and movement of chemical contaminants to the sediments from the water column.

Within the water column, the availability of many chemical contaminants is affected not only by partitioning between the dissolved and particulate phases but also by complexation of dissolved forms. Donat (1994) has been studying the complexation of dissolved copper and cadmium within the Bay and has determined that a major fraction of both elements (>90 percent for copper and approximately 50 percent for cadmium) occurs as organic complexes. The importance of these findings is that the availability and toxicity are both reduced dramatically through organic complexation.

## **Sediment-Associated Resuspension and Transport**

Although chemicals that readily absorb to particles (i.e., particle-reactive) appear to be removed from the system, research by Sanford and colleagues [264, 265, 266, 267] suggests that the frequent and substantial resuspension of fine-grained material can significantly increase the residence time of these chemicals in the water column. Tidal and storm-generated resuspension operate on different temporal and spatial scales and can be moderated by the degree of temperature/salinity stratification of the water column. Newly settled material takes from days to weeks before it is actually buried below the sediment surface layer and incorporated into the sediment bed. Little of the original particulate-bound chemical contaminants remains by the time of burial due both to decay of the fresh organic carbon and recycling of the associated chemical contaminants back into the water column during resuspension.



## Sediment Fluxes and Burial

Preliminary results from the toxics research program indicate that bottom sediments and particle-reactive chemicals are affected by both physical and biogeochemical processes. Riedel and colleagues [223] measured copper and arsenic fluxes and distributions in sediment microcosms with varying densities, types of benthic organisms, and oxygen levels. Levels of oxygen in the overlying water column (anoxic, sub-oxic, or oxic) played a considerable role in the flux of copper and arsenic. Under oxic conditions, significant fluxes of copper occur from the sediments; arsenic fluxes are significant only when benthic densities of active burrowers, such as the polychaete worm *Nereis succinea*, are high. Arsenic fluxes out of the sediment were highest under anoxic conditions, while copper fluxes were actually into the sediments. The benthic flux of arsenic represents a potentially significant source to the water in areas of the Bay that undergo seasonal anoxia. Cornwell and colleagues [161] are examining the distributions of several toxic trace metals in sediments. They are also measuring the benthic flux of these metals directly across the sediment-water interface in various areas of the Bay to assess the importance of this source.

Schaffner and Dickhut [269] have investigated how benthic biogeochemical processes affect the cycling of organic chemical contaminants (i.e., polycyclic aromatic hydrocarbons and PCBs). Preliminary results indicate that macrofauna enhance the loss of organic chemical contaminants from the sediment. Moreover, resuspension by the polychaete worm *Loimia medusa* is of the same

order-of-magnitude as the flux reported for sediment trap studies. This biosuspension can be an important mechanism for the movement of particle-bound materials during low tides or storms and would increase the time particle-reactive chemicals remain in the water column before burial.

Once organic chemical contaminants are deposited to sediments, the potential for degradation by the microbial community also exists. Capone and colleagues [38] have found that degradation rates vary considerably, depending upon the organic chemical contaminant and the redox state of the sediments. Some organic chemical contaminants are readily degraded, even when the microbial community has no prior history with the organic compound. Other chemical contaminants, such as PCBs, are not significantly degraded under any conditions.

## Findings and Conclusions

While scientists generally thought that chemicals incorporated into the sediments were eventually removed from the system, current research indicates that biogeochemical cycling within the sediments may increase the length of time a particulate-bound chemical is mobile and potentially bioactive. Of particular importance within the Chesapeake Bay are both the varying redox regime driven by seasonal anoxia and the presence and type of benthic organisms. Dissolution and reintroduction of particle-bound chemicals appear to be important processes for many chemicals.

### Box 3. Sources of information on transport, fate, and trophic transfers of chemicals in Chesapeake Bay

Chesapeake Bay Environmental Effects Studies Toxics Research Workshop Reports [162,223]  
Contaminant Problems and Management of Living Chesapeake Bay Resources [182]  
Environmental Effects Research on Chesapeake Bay-Toxics Research Program Descriptions [184-187]  
Sources, Cycling, and Fate of Contaminants in Chesapeake Bay [259]

## Trophic Transfers

Inorganic and organic chemicals are readily taken up by phytoplankton, as demonstrated by the work of Sanders and Sellner [261] along with Baker and colleagues [15, 223]. Because phytoplankton form the base of the food chain, contaminants are available for incorporation into higher trophic levels through feeding. Riedel and colleagues [252] are following metals released from sediments through the planktonic food chain, both in the phytoplankton community and in higher trophic levels. In Baker and Roman's research, hydrophobic organic chemical contaminants, associated with larger particles are also associated with the lipid content of the organisms and may be linked in transfer through the food web [15, 223]. In addition, fecal pellet production by zooplankton, although seasonally variable, may be an important mechanism for the transport of organic chemical contaminants to the sediment of the Bay.

Higher trophic levels are also exposed to chemicals dissolved in the water. Thus, two major pathways exist for uptake. The importance of each pathway varies between chemical contaminants. Newell and colleagues [214] are examining the relative importance of these two pathways for the accumulation of PCBs by the American oyster *Crassostrea virginica*.

## Findings and Conclusions

The key linkage in the transport of chemical contaminants through the pelagic food chain appears to be uptake and incorporation of these chemicals into phytoplankton. The potential also exists for dissolved uptake by higher trophic levels. The relative importance of the two pathways deserves attention. Because phytoplankton can act similarly to other particles in the Bay, the shallow depth of the water and the dynamic behavior of sediments underscore the importance of understanding those physical and chemical parameters which govern particle settling and resuspension.

## Chemical Contaminants in Bay Habitats

In their 1987 review of Chesapeake Bay contaminant issues from a regional perspective, Helz and Huggett [150] stated "No matter where we look in the Bay, we find evidence of some chemical contamination... Many of the contaminants found in highly impacted areas are also now found in remote areas, but at much lower concentrations. There are probably no pristine, truly uncontaminated sites left in Chesapeake Bay." The authors conclude that "In highly impacted areas, such as the Elizabeth River and Baltimore Harbor, evidence of adverse impacts upon aquatic organisms and reduced biological diversity exists. It is likely that toxic materials are responsible for these effects. However, pervasive low level contamination occurring in the mainstem of the Bay has not been equivocally linked to any biological deterioration."

The major findings resulting from efforts to better define the nature, magnitude, and extent of Chesapeake Bay toxic problems are summarized below. The findings support the conclusions of the 1987 review article. In the seven years since the article's publication, we have gained a better understanding of chemical contaminant loadings and releases and have documented evidence for adverse effects in Bay habitats beyond areas with known toxics problems. Causal linkages between low levels of chemical contaminants and biological effects are still unclear, yet we have an expanded base of knowledge and understanding on which to target ongoing and future toxics reduction and prevention programs.

Once a chemical enters the Chesapeake Bay's tidal waters through one of the many pathways described above, its transport, transformation, uptake, and ultimate fate are controlled by a series of geochemical, physical, and biological processes (Figure 15) [259]. Beyond understanding the sources of chemical contaminants, we must also understand how and at what concentra-

tions the Bay's living resources are exposed to these chemicals. Elevated concentrations of a chemical do not necessarily equal toxicity; the toxicity of that chemical to a particular organism is determined by the concentration, frequency, and duration of exposure of the organism to the available form of that chemical.

Our understanding of these processes is too limited to enable us to accurately predict the fate and potential impact of chemicals on the Bay's living resources. We can not yet equate loadings with exposure levels in Bay habitats. To define the nature, magnitude, and extent that chemicals are impacting or have the potential to impact the Bay's living resources, concentrations of these chemicals measured in Bay water and sediment habitats must be compared to thresholds above which toxic effects have been observed in either laboratory or field experimentation.

## **Microlayer Contaminant Concentrations**

The boundary between the atmosphere and the Bay's surface waters is often referred to as the surface microlayer. The eggs and larva of some finfish and shellfish float or come into contact with the surface microlayer. The surface microlayer, approximately 50 micrometers to one millimeter in thickness, also serves as a concentration zone for chemicals. Recent studies have found concentrations of metals, pesticides, and other organic chemical contaminants in the surface microlayer at concentrations often higher than the underlying water column (Table 26) [17, 19, 95, 96, 104, 117, 119, 125, 132, 197, 339, 340]. Because of the high concentrations observed and the potential for direct uptake by biota, this layer may represent an important site for the transfer of chemicals both into the water column and the Bay's living resources [258].

Hardy and colleagues [17] concluded there was the potential for significant reductions in the survival of surface-dwelling organisms (neuston) and floating fish eggs based upon a surface

microlayer toxicity model using microlayer concentrations of chemicals measured in Chesapeake Bay. Hall and colleagues [117] concluded that although elevated concentrations of chemicals at potentially toxic concentrations were measured in the surface microlayer during striped bass spawning, no data were available to demonstrate if these concentrations would significantly reduce the survival of these fish during early life stages.

## **Water Column Contaminant Concentrations**

A Chesapeake Bay Water Column Contaminants Critical Issue Forum was held in March 1993 to seek a technical consensus on the relative magnitude and extent of water column contaminant concentrations within Chesapeake Bay. Evidence for whether elevated concentrations of water column chemical contaminants are causing or can cause an adverse impact on a baywide, regional or local scale was presented and discussed. Findings from the forum [49] and a recent synthesis and critical review of evidence for the impacts of pesticides on the Bay system [163] are summarized here.

### **METALS**

The data synthesized for review at the Chesapeake Bay Water Column Contamination Critical Issue Forum suggest that there are not serious, widespread concentrations of metals exceeding EPA water quality criteria or state water quality standards in the mainstem Bay (Table 27; Figure 16) [49, 292]. The data show clearly that concentrations of some metals are elevated in some tributaries compared with mainstem concentrations, but only a very limited number of concentrations exceed water quality criteria and standards (Table 28) [49].

The critical issue forum participants recognized that much of the historical data on metals were values of total recoverable (rather than dissolved) concentrations. The U.S. Geological Survey and the U.S. Environmental Protection

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**Table 26.** Summary of chemicals detected in Chesapeake Bay surface microlayer samples.

Location(s)	Results	Source
Eight sampling stations in Maryland including four marinas, Baltimore Harbor, Chesapeake and Delaware Canal, Choptank and Potomac rivers.	Mean tributyltin concentrations ranged from 54-310 ng/l in the four marinas after monthly sampling over a 12-month period; highest concentrations ranged from 1,049-1,171 ng/l. Tributyltin concentrations ranging from 29-41 ng/l were detected in the Chesapeake and Delaware Canal during May and June, 1986.	Hall et al. 1987d Hall et al. 1986a Hall 1988
Baltimore Harbor and marina in Annapolis, Maryland.	Tributyltin concentrations ranging up to 4,568 ng/l were reported in Baltimore Harbor.	Matthais et al. 1986 Hall 1988
Seven stations in Back Creek and the Severn River near Annapolis, Maryland.	Tributyltin concentrations ranging up to 4,130 ng/l were reported in a Back Creek marina. Mean tributyltin concentration of 971 ng/l for the six Back Creek stations. Tributyltin concentration of 60 ng/l reported at the Severn River Station.	Matthais et al. 1988 Hall 1988
Two stations in Maryland: Susquehanna River, Chesapeake and Delaware Canal, Patapsco, Patuxent, Potomac, Choptank, Nanticoke rivers, and Bay mainstem	Concentrations of chromium, copper, lead, mercury, nickel, silver, and zinc were higher in microlayer samples than bulk water samples. Microlayer samples had a mean total polycyclic aromatic hydrocarbons concentration of 1.64 µg/l compared to a mean bulk water concentration of 0.34 µg/l. Microlayer samples had a mean particulate alkanes concentration of 102 µg/l compared to a mean bulk water concentration of 2.5 µg/l.	Hardy et al. 1987
Total of ten stations located in the Susquehanna, Potomac, Elk, Sassafras, Choptank rivers, and Bay mainstem	Detected microlayer concentrations of tributyltin (0.005-0.28 ng/l) and dibutyltin (0.007-0.071 ng/l); bulk water tributyltin concentrations were all <0.002 ng/l. Microlayer concentrations of aluminum, arsenic cadmium, chromium, copper, lead, nickel, tin, and zinc were generally higher than bulkwater concentrations.	Hall et al. 1988a
Six stations in Maryland: Susquehanna River, Baltimore Harbor, Potomac River, Choptank River, and Bay mainstem.	Microlayer tributyltin concentrations ranged up to 130 ng/l. Total polycyclic aromatic hydrocarbon microlayer concentrations ranged from <0.05 to 20 µg/l. Pesticide and chlorinated organic compounds were largely undetected in microlayer samples with the exception of dieldrin (1-18 µg/l).	Battelle 1988
Four stations in Maryland: Susquehanna, Potomac, Choptank rivers, and Bay mainstem.	Of the 300 organic compounds analyzed for, only four compounds were observed above detection limits in microlayer samples-methylene chloride, bromoform, di-N-butylphthalate, and trans-1,2 - dichlorethene. Sixteen pesticides of the 75 pesticides analyzed in microlayer samples were detected at trace concentrations: alpha/beta/delta/gamma BHC, capten, 4, 4'-DDE, dichlone, dieldrin, endosulfan I, endrin, heptachlor, heptachlor epoxide, isodrin, methoxychlor, nitrofen, and PCNB.	Gucinski et al. 1991

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**Table 27.** Ranges of water column concentrations of selected dissolved metals reported for the mainstem Chesapeake Bay compared with EPA aquatic life criteria.

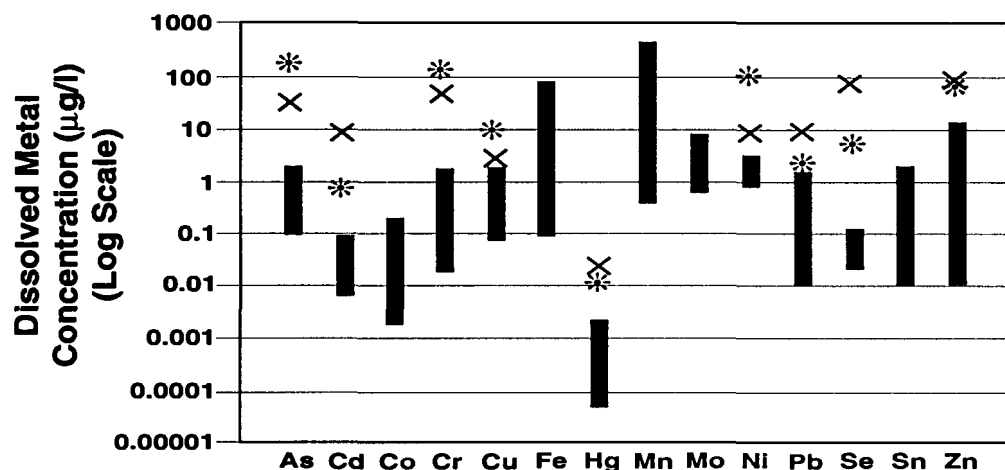
Metal	Dissolved Concentration Range (µg/l)	Freshwater Water Quality Criteria		Marine Water Quality Criteria		Data Source(s)
		Acute	Chronic	Acute	Chronic	
Arsenic	0.1 - 2	360	190	69	36	McGlone 1991; Riedel and Sanders, unpublished data
Cadmium	0.007 - 0.09	3.9 <sup>2</sup>	1.1 <sup>2</sup>	43	9.3	Church, unpublished data; Kingston et al., 1982; Riedel and Sanders, unpublished data
Cobalt	0.002 - 0.2	-	-	-	-	Church, unpublished data; Kingston et al., 1982
Chromium	0.02 - 1.5	16 <sup>4</sup>	11 <sup>4</sup>	1100 <sup>4</sup>	50 <sup>4</sup>	Kingston et al., 1982; Riedel and Sanders, unpublished data
		1700 <sup>2,5</sup>	210 <sup>2,5</sup>	10,300 <sup>3,5</sup>	-	
Copper	0.08 - 2	18 <sup>2</sup>	12 <sup>2</sup>	2.9	-	Church, unpublished data; Kingston et al., 1982; Riedel and Sanders, unpublished data
Iron	0.09 - 100	-	1000	-	-	Church, unpublished data; Kingston et al., 1982; McGlone 1991
Lead	0.01 - 1.5	83	3.2	220	8.5	Church, unpublished data; Kingston et al., 1982
Mercury	0.00005 - 0.0005	2.4	0.012	2.1	0.025	Gilmour, unpublished data
Manganese	0.4 - 400	-	-	-	-	Church, unpublished data; Kingston et al., 1982; McGlone 1991; Riedel and Sanders, unpublished data
Molybdenum	0.6 - 7	-	-	-	-	Kingston et al., 1982
Nickel	0.8 - 3	1,400 <sup>2</sup>	160 <sup>2</sup>	75	8.3	Church, unpublished data; Kingston et al., 1982; Riedel and Sanders, unpublished data
Selenium	0.02 - 0.1	-	-	-	-	McGlone 1991; Riedel and Sanders, unpublished data; Takayanagia and Wang, 1980; Velinsky and Cutter, unpublished data
Tin	0.01 - 1.5	-	-	-	-	Kingston et al., 1982
Zinc	0.1 - 10	120 <sup>2</sup>	110 <sup>2</sup>	95	86	Church, unpublished data; Kingston et al., 1982

**Notes:**

1. Criteria are pH dependent
2. Hardness dependent criteria; 100 µg/l CaCO<sub>3</sub> used
3. Insufficient data to develop a criteria; value presented is lowest observed effect level
4. Chromium VI
5. Chromium III

Source: Chesapeake Bay Program 1993e.

## Chesapeake Bay Mainstem Dissolved Metal Concentration Ranges



**Figure 16.** Ranges of water column concentrations of selected dissolved metals reported for the mainstem Chesapeake Bay from 1979-1992. The range of metal concentrations (■) are compared with the EPA chronic freshwater (\*) and marine (X) water quality criteria. The listed metals are arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), tin (Su), and zinc (Zn). Sources: Chesapeake Bay Program 1993e, Church, unpublished data; Gilmow, unpublished data; Kingston et al. 1982; McGlone 1991; Riedel and Sanders, unpublished data; Takayanagia and Lang 1980; and Velinsky and Cutter, unpublished data.

**Table 28.** Water column concentration ranges of selected metals in Chesapeake Bay tidal tributaries.

Tributary	Aluminum (ug/l)	Arsenic (ug/l)	Cadmium (ug/l)	Chromium (ug/l)	Copper (ug/l)	Lead (ug/l)	Mercury (ug/l)	Zinc (ug/l)	Data Sources
<b>Susquehanna:</b>									
Range (tidal)	<60-120	<3-8	<3	<3	<3-13	<3-4	—	<3-13	4
Mean	78.3	3.8	<3	<3	4.8	3.2	—	9.3	
<b>Potomac River:</b>									
Range (D.C.)	—	<5	<5	<10-32	<25	<50-106	<0.2	<20-64	1
Mean	—	<5	<5	<10	<25	<50	<0.2	36	
<b>Anacostia River:</b>									
Range	—	<5	<5	<10-40	<25	<50	<0.2- 0.7	<20-196	1
Mean	—	<5	<5	13	<25	<50	0.2	46	
<b>Potomac:</b>									
Range (middle)	14-740	<3-8.8	<0.2-4.7	<1.0-150	0.94-37	<1-14	—	<1-270	2
Mean	166.7	3.2	0.4	7.1	3.2	1.8	—	22.4	
<b>C&amp;D Canal:</b>									
Range*	120-190	<2-<5	0.8-4.3	2-5	9-68	<1	—	10-55	6
Mean	70	3.5	2.8	16.6	38.6	<1	—	30.5	
<b>Sassafras River:</b>									
Range	<60-70	<3	<3	<3	<3-5	<3-4	—	5-28	4
Mean	68	<3	<3	<3	4.2	3.4	—	12.8	
<b>Elk River:</b>									
Range	60-90	<3-4	<3	<3-3.5	<3-8	<3-5	—	9-24	4
Mean	70	3.2	<3	3.1	5	3.3	—	15	
<b>Choptank River:</b>									
Range*	156	<3	<1	<3	<6	2.5	—	24	5
Mean	—	—	—	—	—	—	—	—	
<b>Nanticoke River:</b>									
Range	—	<1-2	<1-2	2.5-5.8	<1-2	<1-4.3	<0.2	3.2-48.1	3
Mean	—	1.5	1.5	3.7	1.8	2	<0.2	18.1	

\* = number is based on *one* grab sample.

## Sources:

1. District of Columbia, Department of Consumer and Regulatory Affairs, unpublished data
2. Hall et al. 1992a.
3. Hall et al. 1994.
4. Hall et al. 1988a.
5. Hall et al. 1991b.
6. Hall et al. 1985.

Agency have raised serious concerns regarding the quality (e.g., contamination leading to the reporting of concentrations higher than were actually present) of most historical metals data. In cases in which total recoverable metal concentrations are compared with water quality criteria or standards representing dissolved metal concentrations, an overestimation of the concern for water column metal contamination within Chesapeake Bay may result as the dissolved fraction is a subset of the total recoverable fraction. Concerns were also raised as to whether the standard analytical methods commonly used for analysis of point source effluents were sensitive enough to measure ambient concentrations in the Bay watershed. The findings summarized here should be interpreted with caution given these concerns.

### **Pennsylvania**

Water column data collected through Pennsylvania's Water Quality Network indicate that the metals observed are primarily associated with acid mine drainage in the upper Susquehanna River basin—aluminum, cadmium, lead, and zinc. Exceedences of Pennsylvania water quality standards were generally 2 percent or less at stations sampled since 1988 in the Potomac and Susquehanna basins [42]. Exceedences with greater than 10 percent of the observations above the state water quality standards were documented at all nine stations for aluminum, at two stations for copper, and at one station for lead. Sampling for cadmium and chromium was discontinued at most stations because concentrations of these metals were not detected.

### **Maryland**

Fifty-seven stations throughout Maryland were sampled during 1989 to 1990 to provide data for the development of Maryland's 304(l) list. Sample station sites were selected based on previously collected data which showed where elevated chemical contaminant concentrations had occurred. All metal analyses were for total recoverable concentrations. Those metals closely associated with soils—aluminum, iron, and zinc—were detected in most samples. The majority of the

metals sampled (arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, and silver) were detected in less than 20 percent of all samples collected [49]. Detectable concentrations were observed in less than 1 percent of the collected samples for antimony, hexavalent chromium, and thallium. Of the total recoverable metals concentrations measured, some (principally copper and cadmium) exceeded EPA water quality criteria.

### **District of Columbia**

A review of 1989 to 1990 metals data collected from the District of Columbia's portions of the Potomac and Anacostia rivers showed that chromium, iron, and zinc concentrations exceeded the district's water quality standards [49].

### **Virginia**

A review and synthesis of data from the past 20 years from Virginia's Ambient Water Quality Monitoring Network focused on the analysis and interpretation of statewide data for six metals [289]. Most total recoverable concentration data for arsenic, beryllium, cadmium, lead, and mercury were below detection limits [49]. In the case of copper, 35 percent of the data were above the detection limit.

### **Tidal Tributaries**

Beyond the state water quality monitoring networks, a majority of the available metals concentration data for the Bay's tidal tributaries comes from field studies conducted during the U.S. Fish and Wildlife Service sponsored 1984 to 1990 striped bass contaminant studies and during more recent ambient toxicity assessments of Bay habitats. Findings from these studies are summarized below and in Table 28.

In the Nanticoke River, dissolved concentrations of cadmium, copper, and lead were observed at levels above EPA water quality criteria in striped bass spawning habitats in 1984 [102, 105]. Exceedences of water quality criteria for cadmium and copper were observed during sam-

pling of the Choptank River's spawning habitat in 1987 [123, 124]. In the Potomac River, multiple observations of cadmium, chromium, copper, lead, nickel, and zinc concentrations exceeded water quality criteria in spawning habitats during the 1986 and 1988 to 1990 sampling surveys [111, 112, 115, 116, 117, 118, 126, 127]. Concentrations of cadmium, chromium, copper, lead, and nickel were observed at concentrations exceeding water quality criteria in spawning habitats sampled in 1985, 1987, and 1988 to 1990 in the upper Bay region—Susquehanna Flats, upper mainstem Bay, and Chesapeake and Delaware Canal [103, 105, 106, 111, 112, 115, 116, 117, 118, 123, 124].

During the three years of the Chesapeake Bay ambient toxicity assessment program, some metals exceeded water quality criteria concentrations in the Elizabeth (copper, mercury), Patapsco (copper, nickel), Wye (copper, nickel), Potomac

(cadmium, copper, mercury, nickel), and Middle (copper, lead, nickel, zinc) rivers [110, 113, 114].

### Fall Line

Concentrations measured at the fall line capture the cumulative input of all point and nonpoint sources from the watershed above the fall line, providing an ideal place to measure riverine transport of chemical contaminants to the Bay's tidal waters. Table 29 presents range and mean concentrations of 11 metals at the Bay's nine major fall line sites for dissolved metals; Table 30 shows these concentrations for total recoverable metals. These data, collected through the U.S. Geological Survey National Stream Quality Accounting Network and the Chesapeake Bay Fall Line Toxics Monitoring Program, cover the period from 1979 to 1992.

Exceedences of both the acute and chronic EPA water quality criteria occurred for cadmium,

**Table 29.** Chesapeake Bay fall line concentrations of selected dissolved metals<sup>1</sup>.

Fall Line	Aluminum	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc
Susquehanna	<10-600 60.2*	<0.6-2 0.78*	<0.1-4 0.52*	<1-10 1.80	<1-10 2.43	<0.06-13 1.19*	<0.1-0.5 0.09*	<1-11 3.43	<1 —	<1-1 —	<3-130 10.3
Patuxent	<10-380 46.0*	<1-2 0.82*	<1-4 0.58*	<1-40 2.35*	<1-7 3.54	<1-10 1.66*	<0.1-41 1.02*	<1-11 3.32*	<1-2 —	<1-3 —	<3-480 25.7
Potomac	<10-700 74.6*	<1-3 0.83*	<1-12 0.58*	<1-30 4.17*	<1-8 2.57*	<1-60 2.75*	<0.1-2.1 .14*	<1-5 1.63*	<1 —	<1-1 —	<3-83 12.7*
Rappahannock	<10-250 49.7*	<1.3 0.74*	<1-3 0.80*	<1-20 1.94*	<1-7 2.3	<1-10 1.73*	<0.1-1.4 0.08*	<1.6 1.55*	<1 —	<1-1 —	<3-26 9.51*
Pamunkay	<10-120 34.0*	<1-1 1*	<1-5 0.72*	<1-20 2.87*	1-10 3.06	<1-12 2.06*	<0.1-0.4 0.08*	<1-6 1.41*	<1 —	<1-1 —	<3-44 11.28*
Mattaponi	<10-400 48.3*	<1-3 0.84*	<1-3 0.89*	<1-10 1.69*	<1-6 1.44*	<1-17 2.10*	<0.1-0.4 0.04*	<1-8 1.55*	<1 —	<1-1 —	<3-64 9.28*
Appomattox	<10-400 61.2*	<1-2 0.77*	<1-2 0.47*	<1-30 2.09*	<1-5 2.06*	<1-6 1.88*	<0.1-0.7 0.07*	<1-20 1.67*	<1 —	<1-1 —	<3-30 6.06*
James	<10-600 91.1*	<1-2 0.85*	<1-3 0.67*	<1-20 0.90*	<1-9 2.19*	<1-17 1.43*	<0.1-1 0.07*	<1-10 1.39*	<1 —	<1-2 —	<3-54 5.48*
Choptank	<10-440 90.7*	<1-7 0.93*	<1-8 0.86*	<1-20 3.63*	<1-46 4.09*	<1-6 1.73*	<0.1-1.8 0.11*	<1-18 2.91*	<1-1 —	<1-2 —	<3-62 15.6*

1. Range and mean concentrations (µg/l) from samples collected at U.S. Geological Survey NASQAN stations during the period 1979-1992.

\* Mean value is estimated by using a log probability regression to predict the values of data below the detection limit.

Sources: Phillips, Personal Communication; Chesapeake Bay Program, 1993e.



chromium, copper, and zinc, and of the chronic water quality criteria for aluminum, lead, mercury, and silver (Table 30). No exceedences of acute or chronic water quality criteria for arsenic, nickel, or selenium occurred at any of the nine fall line stations. Since most fall line dissolved metals concentrations were not significantly above the criteria concentrations, widespread exceedences of acute and chronic EPA water quality criteria are not expected in waters just below the fall line.

## PESTICIDES

Johnson and colleagues [163] assembled a data base of ambient pesticide concentration data for the Chesapeake Bay basin containing 48 separate studies conducted since the late 1970s. Of 12 targeted pesticides, atrazine followed by alachlor, carbofuran, chlordane, metolachlor, simazine, and toxaphene were surveyed in at least three Eastern Shore and three western shore tributaries, suggesting good spatial assessment of

contaminant levels. The remaining five target pesticides—linuron, diflufenzuron, chlorpyrifos, chlorothalonil, and permethrin—received limited spatial assessment. Only six of the target pesticides have EPA aquatic life criteria or drinking water Maximum Contaminant Level standards. Of these six pesticides, only alachlor, atrazine, and simazine were observed in concentrations exceeding the drinking water Maximum Contaminant Level (Table 31). The Maximum Contaminant Level was exceeded for atrazine in four sections of the tidal Bay as well as at sites sampled in the Conestoga and Little Conestoga rivers in Lancaster, Pennsylvania. It was also exceeded for alachlor in one section of the tidal Bay and in the Conestoga and Little Conestoga rivers, and for simazine in one section of the tidal Bay.

Detection of pesticides occurs most frequently in the spring and summer months, corresponding to the highest rates of pesticide application. The

**Table 30.** Chesapeake Bay fall line concentrations of selected total recoverable metals<sup>1</sup>.

Fall Line	Aluminum	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc
Susquehanna	80 - 12,000 1,099	<1 - 6 0.81*	<1 - 20 0.47*	<1 - 30 5.58*	<1 - 23 4.27	<1 - 1800 18.7	<1 - 1.4 0.13*	<1 - 11 3.43	<1 - 1 —	<1 - 7 —	<10 - 170 25.8*
Patuxent	— —	<1 - 2 1.07	<1 - 3 —	<10 - 20 14.7*	3 - 9 6.57	<1 - 190 21.2	<0.1 - 0.5 0.12*	<2 - 16 6.56*	<1 - <1 —	<1 - 1 —	<20 - 100 37.9*
Potomac	80 - 15,000 2,205	<1 - 3 1.11*	<1 - 3 0.83*	<10 - 40 12.1*	1 - 34 7	<1 - 1,300 47.3	<0.1 - 0.5 0.12*	<1 - 120 10.9	<1 - <1 —	<1 - 3 —	<10 - 150 31.6*
Rappahannock	— —	<1 - 2 1.11*	<1 - 1 1*	<10 - 40 17.9*	1 - 16 6.17	<1 - 10 3.83	<0.1 - 0.7 0.15*	<1 - 35 5.83	<1 - <1 —	<1 - <1 —	10 - 200 48.3
Pamunkey	— —	<1 - 2 1.03*	<1 - 5 1.56*	10 - 30 15.8	2 - 12 6.08	<1 - 15 4.25	<0.1 - 1 0.16*	<1 - 9 2.83*	<1 - <1 —	<1 - <1 —	10 - 460 74.2
Mattaponi	— —	<1 - 5 1.57*	<1 - 7 1.74*	<10 - 20 12.6*	1 - 7 3.36	<1 - 13 5.64	<0.1 - 0.2 —	<1 - 6 3.1	<1 - <1 —	<1 - <1 —	10 - 790 104
Appomattox	— —	<1 - 2 1.14*	<1 - 2 0.92*	<10 - 30 12.6*	1 - 7 4.25	<1 - 6 2.15*	<0.1 - 1.4 0.24*	<1 - 12 3.80*	<1 - <1 —	<1 - 2 —	10 - 50 24.2
James	100 - 5,700 1,635	<1 - 3 0.32*	<1 - 4 0.57*	<1 - 32 5.52*	1 - 84 6.51	<1 - 260 10.1*	<0.1 - 0.6 0.05*	<1 - 18 4.46*	<1 - 6 —	<1 - 1 —	<10 - 110 27.4*
Choptank	— —	<1 - 5 1.57	<1 - 3 0.85*	<10 - 30 14.7*	1 - 46 9.5	<1 - 13 4.42*	<0.1 - 0.5 0.12*	<2 - 27 6.16*	<1 - 1 —	<1 - <1 —	<10 - 160 30.4*

1. Range and mean concentrations (µg/l) from samples collected at U.S. Geological Survey NASQAN stations during the period 1979-1992.

\* Mean value is estimated by using a log probability regression to predict the values of data below the detection limit.

Sources: Phillips, Personal Communication; Chesapeake Bay Program, 1993e.

highest reported concentrations of pesticides in surface water were often associated with storms. Few data in the Bay watershed, however, have been collected at the spatial and temporal frequency necessary to fully characterize the variability inherent in environmental concentrations of pesticides [163].

### Fall Line

Pesticides detected through the Chesapeake Bay Fall Line Toxics Monitoring Program at the Susquehanna, Potomac, and James rivers from 1990 to 1993 included 2,4-D, alachlor, aldrin, alpha-chlordane, atrazine, cyanazine, DDT, diazinon, dicamba, dieldrin, fenvalerate, gamma-chlordane, hexazinone, malathion, metolachlor, oxychlordane, picloram, prometon, simazine, and terbacil [193, 194, 195]. The frequency of detection and measured concentra-

tions of these pesticides, however, were generally very low. No detectable concentrations were found of permethrin or more than the 60 other pesticides analyzed at the three major fall line stations [193]. Quarterly baseflow sampling through the U.S. Geological Survey National Stream Quality Accounting Network yielded no detectable concentrations of pesticides at the other six major Bay fall line stations with the exception of one measurable concentration of diazinon at the Choptank River fall line (Table 32). Table 33 summarizes the range and mean concentration of pesticides monitored at the Susquehanna, Potomac, and James river fall line stations from 1992 to 1993.

### ORGANIC CHEMICALS

With a few notable exceptions, the water column organic contaminant data—polycyclic

**Table 31.** Summary of selected pesticides detected in Chesapeake Bay water column samples.

Pesticide	Number of Studies	Number of years for which Data Exists	Number of Bay segments with Data <sup>1</sup>	Total Number of Samples Analyzed	Percent of Sample with Detectable Concentrations	Number of Bay Segments Exceeding the MCL or WQC <sup>2</sup>
Alachlor	14	8	21	428	21%	1 (MCL)
Atrazine	24	14	28	1,061	67%	4 (MCL)
Carbofuran	4	3	13	208	1%	0 (MCL)
Chlordane	10	5	20	325	11%	0 (MCL, WQC)
Chlorpyrifos	3	2	11	204	9%	0 (WQC)
Chlorohalonil	0	—	—	0	—	NA
Diflubenzuron	1	1	4	133	0%	NA
Linuron	2	2	5	32	72%	NA
Metolachlor	11	6	19	321	47%	NA
Permethrin	5	2	7	170	0%	NA
Simazine	11	8	20	553	62%	1 (MCL)
Toxaphene	8	5	17	199	0%	NA

1. Number of different segments from the Chesapeake Bay Segmentation Scheme from which the analyzed samples had been collected.
2. Number of Chesapeake Bay segments where pesticide concentrations exceeded the EPA drinking water Maximum Contaminant Level (MCL) or the EPA Water Quality Criteria (WQC). NA indicates pesticides for which there is no MCL or WQC.

Source: Johnson et al., In Review.

**Table 32.** Chesapeake Bay fall line concentrations of pesticides: 1979-1992<sup>1</sup>.

Fall Line	Pesticides Above Detection Limits	Pesticide	Range	Mean	Number of Samples
Susquehanna	11/50 <sup>2</sup>	2,4-DP	<0.01-0.01	—	21
		2,4-D	<0.01-0.3	0.08*	49
		2,4,5-D	<0.01-0.3	0.005*	48
		Alachlor	<0.1-0.1	—	30
		Atrazine	<0.1-1.2	0.18	73
		Cyanazine	<0.1-0.7	0.087*	43
		Malathion	<0.01-0.01	—	42
		Metolachlor	<0.1-0.5	0.078*	30
		Prometone	<0.1-0.3	—	64
		Prometryne	<0.1-0.7	—	68
		Simazine	<0.1-0.2	0.069*	68
Patuxent	No pesticides detected.				
Potomac	9/36 <sup>3</sup>	2,4-D	<0.01-0.14	0.026*	35
		2,4,5-T	<0.01-0.04	0.003*	35
		Atrazine	<0.1-0.5	0.159*	35
		DDD	<0.01-0.01	—	36
		DDE	<0.01-0.01	—	36
		Dieldrin	<0.01-0.01	—	36
		Prometone	<0.1-0.2	0.071*	30
		Prometryne	<0.1-0.2	—	34
		Simazine	<0.1-0.39	0.1	34
Rappahannock	No pesticides detected.				
Mattaponi	No pesticides detected.				
Pamunkey	0/22 <sup>4</sup>				
Appomatox	No pesticides detected.				
James	13/50 <sup>2</sup>	2,4-D	<0.01-0.08	—	38
		2,4,5-T	<0.01-0.04	—	38
		Alachlor	<0.1-1.0	—	42
		Aldrin	<0.01-0.01	—	58
		Atrazine	<0.1-1.0	—	64
		Atrazine	<0.1-0.3	—	22
		DDT	<0.01-0.01	—	58
		Diazinon	<0.01-0.01	—	35
		Malathion	<0.01-0.01	—	35
		Metolachlor	<0.1-0.1	—	42
		Prometone	<0.1-0.2	—	64
		Silvex	<0.01-0.01	—	38
		Simazine	<0.01-0.1	—	64
Choptank	1/24 <sup>4</sup>	Diazinon	<0.01-0.02	—	11

1. Range and means concentrations (µg/l) from samples collected at the U.S. Geological Survey NASQAN stations during the period 1979-1992.
2. 2,4,-DP, 2,4-D, 2,4,5-T, 3-hydroxy carbofuran, alachlor, aldrin, aldicarb sulfoxide, aldicarb sulfone, aldicarb, ametryne, atrazine, atrazone, chlorpyrifos, chlordane, cyanazine, cyprazine, DDD, DDE, DDT, DEF, diazinon, dieldrin, disyston, endosulfan, endrin, fonofos, heptachlor, heptachlor epoxide, lindane, malathion, methomyl, methoxylchlor, methyl parathion, metribuzin, metolachlor, mirex, oxyamyl, parathion, phorate, propazine, prometone, prometryne, sevin, silvex, simetryne, simazine, simetone, toxaphene, trifluralin.
3. 2,4,-DP, 2,4-D, 2,4,5-T, aldrin, ametryne, atrazine, atrazone, chlordane, cyanazine, cyprazine, DDD, DDE, DDT, diazinon, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, malathion, methoxylchlor, methyl parathion, mirex, parathion, propazine, prometone, prometryne, silvex, simetryne, simazine, simetone, toxaphene.
4. 2,4,-DP, 2,4-D, 2,4,5-T, aldrin, chlordane, DDD, DDE, DDT, diazinon, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, malathion, methoxylchlor, methyl parathion, mirex, parathion, silvex, toxaphene.

\* Mean value is established by using a log probability regression to predict the values of data below the detection limit.

Sources: Phillips, Personal Communication; Chesapeake Bay Program, 1993e.

**Table 33.** Chesapeake Bay fall line concentrations of pesticides: 1992-1993<sup>1</sup>.

Pesticide	Susquehanna River		Potomac River		James River	
	Range	Mean	Range	Mean	Range	Mean
Alachlor	<2.5 - 23.1	4.4	<2.5 - 20.9	4.1	<7.5 - 20.2	2.9
Aldrin	<0.2 - 1.6	0.2	<0.2 - 2.3	0.2	<0.2 - 2.4	<0.2
Atrazine	<1.3 - 2,937	50.4	<1.3 - 579	147.9	<1.3 - 476.3	37.9
alpha-Chlordane	<0.1 - 17.0	1.0	<0.1 - 5.3	0.7	<0.1 - 17.2	1.4
gamma-Chlordane	<0.1 - 9.5	0.5	<0.1 - 3.5	0.3	<0.1 - 8.5	0.7
Cyanazine	<2.4 - 108	16.9	<2.4 - 212.4	45.7	<2.4 - 24.9	4.3
4, 4' - DDT	<0.5 - 1.4	<0.5	<0.5 - 1.7	<0.5	<0.5 - 1.4	<0.5
Diazinon	<2.5 - 17.7	<2.5	<2.5 - 10.0	<2.5	<2.5 - 11.6	<2.5
Dieldrin	<0.2 - 5.5	0.4	<0.2 - 4.1	0.8	<0.2 - 2.4	0.2
Fenvalerate	<0.6 - 3.8	<0.6	<0.6 - 3.5	<0.6	<0.6 - 4.0	<0.6
Hexazinone	<0.8 - 16.3	2.1	<0.8 - 19.7	1.7	<0.8 - 16.8	3.4
Malathion	<2.3 - 7.7	<2.3	<2.3 - 11.5	<2.3	<2.3 - 11.6	<2.3
Metolachlor	1.4 - 139.6	28.6	<0.7 - 358	83.0	<0.7 - 210.3	15.7
Oxychlordane	<0.1 - 11.1	0.6	<0.1 - 31.8	1.5	<0.1 - 12.1	0.8
Permethrin <sup>2</sup>	<1.7 - 7.1	<1.7	<1.7 - 15.1	<1.7	<1.7 - <1.7	<1.7
Prometon	<1.6 - 18.9	3.7	<1.6 - 17.0	8.1	<1.6 - 18.1	<1.6
Simazine	<2.0 - 91.3	140	<2.0 - 142.8	50.0	<2.0 - 369.6	25.1

1. Particular water concentrations ( $\mu\text{g/l}$ ) from samples collected through the Chesapeake Bay Fall Line Toxics Monitoring Program from March 1992 - February 1993; below detection limit values set to detection limit in the calculation of the mean.
2. Cis and trans.

Sources: Maryland Department of the Environment and Metropolitan Washington Council of Governments 1994a, 1994b.

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**Table 34.** Summary of organic compound concentrations in Chesapeake Bay water column samples.

Region/Tributary	Year(s)	Compounds/Concentrations Observed	Sources
Susquehanna River	1988	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1988a Hall et al. 1989
Upper Chesapeake Bay	1989	Detectable concentrations of heptachlor epoxide (0.008 µg/l), endosulfan (0.006 µg/l), dieldrin (0.005 µg/l), and 4, 4-DDT (0.014 µg/l) of the total of 14 organics compounds analyzed <sup>1</sup> .	Hall et al. 1991b Hall et al. 1992b
	1990	Detectable concentrations of pyrene (0.42 µg/l) of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1992a Hall et al. 1992b
Chesapeake and Delaware Canal	1985, 1987	One detectable concentration (benzene - 3 µg/l (1985)) of the total of 116 organic compounds analyzed <sup>2</sup> .	Hall 1985, Hall et al. 1987a Hall et al. 1987c, Hall et al. 1988b
	1986, 1987, 1988, 1989	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1987c, Hall et al. 1986b Hall et al. 1987e, Hall et al. 1988a Hall et al. 1988b, Hall et al. 1989 Hall et al. 1991b, Hall et al. 1992b
Middle River	1992, 1993	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1994
Patapsco River	1990	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1991a
	1991	No detectable concentrations of the 19 organic compounds analyzed <sup>5</sup> .	Hall et al. 1992c
Patuxent River	1985	No detectable concentrations of the 19 organic compounds analyzed <sup>3</sup> .	Hall 1985, Hall et al. 1987a
	1986, 1987, 1988, 1989	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1987c, Hall et al. 1986b Hall et al. 1987e, Hall et al. 1988a Hall et al. 1988b, Hall et al. 1989 Hall et al. 1991b, Hall et al. 1992b
Potomac River	1985	No detectable concentrations of the 21 organic compounds analyzed <sup>3</sup> .	Hall 1985 Hall et al. 1987a
	1986	No detectable concentrations of the 111 organic compounds analyzed <sup>4</sup> .	Hall et al. 1986b Hall et al. 1987e
	1988	Only two detectable concentrations (Chlordane - 0.152 µg/l; DDD - 0.097 µg/l) of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1988a Hall et al. 1989
	1987, 1989, 1990	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1987c, Hall et al. 1988b Hall et al. 1991b, Hall et al. 1991a Hall et al. 1992b, Hall et al. 1992a Hall et al. 1992b
	1991	No detectable concentrations of the 19 organic compounds analyzed <sup>5</sup> .	Virginia State Water Control Board 1991
Rappahannock River	1985	No detectable concentrations of the 21 organic compounds analyzed <sup>2</sup> .	Hall 1985, Hall et al. 1987a
	1986, 1987, 1988, 1989	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1987c, Hall et al. 1986b Hall et al. 1987e, Hall et al. 1988a Hall et al. 1988b, Hall et al. 1989 Hall et al. 1991b, Hall et al. 1992b

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**Table 34 (con't.).** Summary of organic compound concentrations in Chesapeake Bay water column samples.

Region/Tributary	Year(s)	Compounds/Concentrations Observed	Sources
Pamunkey River	1985	No detectable concentrations of the 21 organic compounds analyzed <sup>3</sup> .	Hall 1985, Hall et al. 1987a
	1986, 1987, 1988, 1989	One detectable concentration (Chlordane - 0.05 µg/l (1988) of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1987c, Hall et al. 1986b Hall et al. 1987e, Hall et al. 1988a Hall et al. 1988b, Hall et al. 1989 Hall et al. 1991b, Hall et al. 1992b
James River	1985	No detectable concentrations of the 21 organic compounds analyzed <sup>3</sup> .	Hall 1985, Hall et al. 1987a
	1986, 1987, 1988, 1989	Two detectable concentrations (PCB Arochlor 1248 0.04 µg/l (1986); Chlordane - 0.03 µg/l (1988)) of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1987c, Hall et al. 1986b Hall et al. 1987e, Hall et al. 1988a Hall et al. 1988b, Hall et al. 1989 Hall et al. 1991b, Hall et al. 1992b
Elizabeth River	1989, 1990	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	VA Water Control Board 1991 Hall et al. 1991a
Elk River	1988	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1988a Hall et al. 1989
Sassafras River	1988	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1988a Hall et al. 1989
Wye River	1990, 1992 1993	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1991a Hall et al. 1994
	1991	No detectable concentrations of the 19 organic compounds analyzed <sup>5</sup> .	Hall et al. 1992c
Choptank River	1985	No detectable concentrations of the 21 organic compounds analyzed <sup>3</sup> .	Hall 1985 Hall et al. 1987c
	1986, 1987, 1988, 1989	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .  Hall et al. 1991b, Hall et al. 1992b	Hall et al. 1987c, Hall et al. 1986b, Hall et al. 1987e, Hall et al. 1988a Hall et al. 1988b, Hall et al. 1989,
Nanticoke River	1984	No detectable concentrations of the 62 organic analyzed <sup>6</sup> .	Hall 1984, Hall et al. 1985
	1985	No detectable concentrations of the 21 organic compounds analyzed <sup>3</sup> .	Hall 1985 Hall et al. 1987a
	1986, 1987, 1988, 1989, 1992, 1993	No detectable concentrations of the 14 organic compounds analyzed <sup>1</sup> .	Hall et al. 1987c, Hall et al. 1986b Hall et al. 1987e, Hall et al. 1988a Hall et al. 1988b, Hall et al. 1989 Hall et al. 1991b, Hall et al. 1992b Hall et al. 1994
Maryland (41 Subbasins)	1989, 1990	No detectable concentrations of any of the 94 organic priority pollutants analyzed <sup>7</sup> .	MD Dept. of the Environment unpublished data (a), Chesapeake Bay Program 1993e
Virginia (Statewide)	1970-1990	Majority of the available PCBs data (95%) were below detection limit.	Tingler et al. 1990

**Table 34 (con't.).** Summary of organic compound concentrations in Chesapeake Bay water column samples.**Notes:**

1. Anthracene, benzo[a]anthracene, chlordane, chrysene, DDE, fluoranthene, fluorene, PCB Arochlor 1248, PCB Arochlor 1254, PCB Arochlor 1260, perylene, phenanthrene, pyrene, toxaphene.
2. Total of 19 pesticides, 7 PCB arochlors, 11 phenolic compounds, 45 base-neutral organic compounds, and 34 volatile organic compounds.
3. Acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene + benzo[k]fluoranthene, benzo[g,h,i]perylene, chlordane, chrysene, DDE, dibenzo[a,h]anthracene, fluorene, fluoranthene, indeno[1,2,3-c,d]pyrene, naphthalene, PCB Arochlor 1248, PCB Arochlor 1254, PCB Arochlor 1260, phenanthrene, pyrene, toxaphene.
4. Total of 19 pesticides, 7 PCB arochlors, 11 phenolic compounds, 39 base-neutral organic compounds, and 35 volatile organic compounds.
5. Alachlor, anthracene, atrazine, benzo[a]anthracene, chlordane, cyanazine, DDE, fluoranthene, fluorene, metolachlor, PCB Arochlor 1248, PCB Arochlor 1254, PCB Arochlor 1260, perylene, phenanthrene, pyrene, simazine, toxaphene.
6. Total of 3 pesticides, 11 phenolic compounds, 3 PCB Arochlors, and 45 base-neutral organic compounds.
7. Total of 94 organic priority pollutants: 30 volatiles, 57 semi-volatiles, and 7 PCB arochlors.

aromatic hydrocarbons and polychlorinated biphenyls—for Chesapeake Bay and its surrounding watershed are very limited largely due to the expense of chemical analysis which prohibits routine monitoring. Detection of measurable organic chemical concentrations is extremely rare in Bay basin waters (Table 34). Elevated concentrations of tributyltin have been measured and detected in many Bay habitats (Table 35). Those polycyclic aromatic hydrocarbons listed as Chesapeake Bay Toxics of Concern were detected at very low concentrations at the Susquehanna, Potomac, and James river fall lines in 1992 and 1993 (Table 36).

Widespread non-detection of these organic chemicals is due to several factors: 1) most organic chemical contaminants exist at levels below conventional analytical detection limits (i.e., below part per billion concentrations); 2) sampling and analytical problems are associated

with making water column measurements of organic chemical contaminants; and 3) most of these hydrophobic compounds readily partition to sediments and biota [49].

## **FINDINGS AND CONCLUSIONS**

### **Microlayer**

The surface microlayer may be an important site for the transfer of chemicals into the water column and to Bay's living resources because of the high concentrations observed. There are limited data and evidence, however, about the direct biological effects to organisms coming into contact with the surface microlayer.

### **Metals**

No widespread occurrences of measured metal concentrations exceeding EPA water quality criteria or state water quality standards exist in the

#### **Box 4. Sources of information on Chesapeake Bay water column contaminant concentrations**

*Chesapeake Bay Ambient Toxicity Assessment Program Reports [110,113,114]*  
*Chesapeake Bay Striped Bass Contaminant Studies [77,78,102,103,105,106,107,111,112,115,117,118,123,124,126,127]*  
*Chesapeake Bay Water Column Contaminant Concentrations Critical Issue Forum Proceedings [49]*  
*Comprehensive Review of Selected Toxic Substances - Environmental Samples in Virginia [289]*  
*The Characterization of the Chesapeake Bay: A Systematic Analysis of Trace Elements [166]*

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**Table 35.** Concentrations of tributyltin reported in Chesapeake Bay water column samples.

Location	Results	Source
Chesapeake and Delaware Canal, Potomac River, Choptank River, four marinas.	Mean water column concentrations (monthly sampling over twelve months) ranged 51-408 ng/L in four marinas. Peak concentrations were reported in May and June in the marinas. A maximum value of 998 ng/L was reported. Concentrations of 20-24 ng/L were reported in the Potomac River.	Hall et al., 1987b
Seven stations in the Back Creek/Severn River area of Maryland	Maximum water column concentrations of 1171 and 1801 ng/L were reported in two marinas. Mean concentrations of 435 and 291 ng/L were reported in the two marinas after bi-weekly sampling for four months. Peak concentrations occurred in early spring followed by significant reductions during the summer and early fall. The highest concentration reported in the receiving system (Severn River) was 48 ng/L. Mean concentrations in the Severn River were 22 ng/L.	Hall et al., 1987d
Marina in Annapolis, Maryland	Water column concentrations of 71 ng/L reported.	Matthias et al. 1986
Seven stations in the Back Creek/Severn River area of Maryland	Water column concentrations ranging 142-367 ng/L were reported in Back Creek. Concentrations of 34 ng/L were reported in the Severn River.	Matthias et al. 1988
Spa Creek, Annapolis, MD	Water column twenty week average concentrations were 99, 121, 47, and 22 ng/L at four stations located equidistantly away from a marina area. A maximum concentration of 530 ng/L was reported.	Batiuk, 1987
Solomons on Back Creek and Patuxent River, MD	Water column twenty week average concentrations were 52, 47, 21, and 19 ng/L at four stations located equidistantly away from a marina area. A maximum concentration of 170 ng/L was reported.	Batiuk, 1987
Oxford adjacent to Trend Avon River, MD	Water column twenty week average concentrations were 34, 30, 23, and 24 ng/L at four stations located equidistantly away from a marina area. A maximum concentration of 60 ng/L was reported.	Batiuk, 1987
Plain Dealing Creek, near Oxford, MD	Water column twenty week average concentrations were 18, 29, 28, and 16 ng/L at four stations located in the Trend Avon River (non marinas). A maximum TBT concentration of 91 ng/L was reported.	Batiuk, 1987
Sarah Creek and Elizabeth River area of Virginia	Water column concentrations ranged <1-98 ng/L in Sarah Creek which contained several recreational marinas. Concentrations ranging from 10-100 ng/L were reported in various marinas. Concentrations of approximately 52 and 67 ng/L were reported in the Elizabeth River.	Huggett et al., 1986
Sarah Creek and Hampton Roads-James River-Elizabeth River system, Virginia	Water column concentrations ranging from non-detectable to 76 ng/L were reported in Sarah Creek during June-Sept. Concentrations ranged 4-670 ng/L in the Hampton River. Concentrations during June-Sept ranged from non-detectable to 920 ng/L in the Hampton Roads-James River-Elizabeth River system.	Westbrook et al., 1986
Patapsco River, Annapolis marina mainstem Bay in Maryland; Hampton Roads-Elizabeth River areas of Virginia	Water column concentrations of 2.5-6.3 ng/L were reported in the Patapsco River. A concentration of 61 ng/L was reported in an Annapolis marina. Concentrations in the Hampton Roads-Elizabeth River area of Virginia ranged from 16-66 ng/L. Concentrations in the mainstem Bay ranged 2.3-9.1 ng/L.	Olson and Brinkman, 1986

Source: Adapted from Hall 1988.



**Table 36.** Chesapeake Bay fall line concentrations of selected polycyclic aromatic hydrocarbons: 1992-1993<sup>1</sup>.

Organic Compound	Susquehanna River		Potomac River		James River	
	Range	Mean	Range	Mean	Range	Mean
Benzo[a]anthracene	<1.1 - 21.9	2.3	<1.1 - 12.4	1.3	<1.1 - 27.2	4.6
Benzo[a]pyrene	<2.0 - 55.1	2.7	<2.0 - 11.4	<2.0	<2.0 - 137.2	8.2
Fluoranthene	<0.3 - 18.9	3.5	<0.3 - 10.5	1.6	<0.3 - 196.8	12.4
Naphthalene	<0.2 - 39.5	2.8	<0.2 - 19.8	4.0	<0.2 - 34.8	3.3

1. Combined particulate and dissolved water concentrations (ng/L) from samples collected through the Chesapeake Bay Fall Line Toxics Monitoring Program from March 1992 - February 1993; below detection limit values set to detection limit in the calculation of the mean.

Sources: Maryland Department of the Environment and Metropolitan Washington Council of Governments 1994a, 1994b.

mainstem Bay. The majority of Bay tributary water column metals data collected over the past two decades show that metal concentrations are usually below analytical detection limits. Measured concentrations of metals were higher in some non-tidal and tidal tributaries compared to the mainstem Bay, with a very limited number exceeding EPA water quality criteria and/or state water quality standards (generally cadmium, chromium, copper, lead, nickel, and zinc). As most of the metals data were reported as total recoverable concentrations, it is difficult to assess the potential risks to living resources when EPA criteria and state standards have focused on the dissolved fraction—the portion that is available to aquatic resources.

### Pesticides

Pesticides in the water may pose a risk to living resources during and shortly after storms in the spring and summer when they are most heavily used. The highest water column concentrations have been generally measured in non-tidal freshwater streams close to the site of application, with very few observed concentrations above existing aquatic life criteria or drinking water standards.

### Organic Chemicals

Limited data for tidal and non-tidal waters indicate that, throughout the Bay, concentrations of organic chemical contaminants are generally below conventional analytical detection limits (i.e., below part per billion concentrations) and most organic chemical contaminants readily attach to sediment particles and become imbedded in the bottom sediments or are incorporated into biota.

### Sediment Contaminant Concentrations

Sediment contamination problems have been documented for an increasing number of areas in this country including the Chesapeake Bay. Sediments are a major reservoir for metals and organic chemical contaminants because these chemicals adsorb to particles. Sediment concentrations of these chemical contaminants are, therefore, typically higher than they are in the water column. Changes in physical or chemical characteristics of the sediment environment or the overlying water column can cause these sediment-bound chemicals to be released back into the water column.

Urban stormwater runoff, atmospheric deposition, industrial and municipal point source discharges, and shoreline erosion contribute metals, pesticides, and other organic chemical contaminants to riverine and Bay sediments. Chemical weathering and erosion are natural sources of metals, but increased concentrations result from human activities. Most sediment contamination by organic chemicals directly results from human activities.

A Chesapeake Bay Contaminated Sediment Critical Issue Forum was held to seek a technical consensus on the relative magnitude and extent of contaminated sediments within Chesapeake Bay. The forum participants also addressed the question of whether contaminated sediments are causing or can cause an impact (e.g., bioaccumulation, toxicity) on the Chesapeake Bay on a baywide, regional, or local scale. Findings described below are summarized from the forum proceedings [48] and a recent review of Chesapeake Bay contaminated sediments data [76].

## ***EVALUATION OF POTENTIAL TOXICITY***

A variety of approaches have been used to determine sediment concentrations of chemical contaminants which pose risks to aquatic organisms [295]. One approach, developed originally by Long and Morgan [178] for use in the NOAA National Status of Trends Program and refined by MacDonald [181], estimates the probability of adverse biological effects over a range of sediment contaminant concentrations based on matched sediment toxicity/sediment chemistry data. For each chemical, two concentrations, the No Observed Effect Level (NOEL) and the Probable Effects Level (PEL), were estimated [181]. Concentrations above the PEL are considered to pose a considerable risk of adverse effects to aquatic life, but such effects are not certain to occur. At intermediate concentrations between the NOEL and PEL concentrations, adverse effects are considered possible, but not probable;

adverse effect are considered unlikely below the NOEL concentration.

The NOEL and PEL values were derived from a wide variety of field and laboratory studies utilizing sediments and aquatic organisms from many different areas contaminated with a wide variety of chemicals. These NOEL and PEL values can help determine the potential for sediment contaminants to induce toxic effects, but they cannot be used by themselves to identify sediments causing toxic effects in aquatic biota. While these values have limitations, they are probably the best benchmark available to generally evaluate the relative risk to aquatic life posed by sediment contaminants [76].

Defining the spatial resolution is key in assessing the degree of sediment contamination in the Bay and its tidal tributaries from a management perspective. Elevated concentrations of sediment contaminants may occur in localized areas (e.g., marinas) of a river that represent only a tiny fraction of the total surface area of the Bay. These small contaminated areas may be of local or regional concern but do not provide an overall picture of the degree of contamination in the Bay.

## ***SPATIAL DISTRIBUTION***

Recent data from four sources were evaluated to determine the magnitude and extent of sediment contamination in the Chesapeake Bay and its tributaries. The Maryland Department of the Environment and the Virginia Department of Environmental Quality through the Chesapeake Bay Sediment Contaminant Monitoring Program collected sediment contaminant data from 1984 to 1991 which were combined and evaluated. These studies were augmented with data collected at the 17 NOAA National Status and Trends Program sites (1984 to 1987) and the 62 EPA Environmental Monitoring and Assessment Program sites (1990 only). Both national monitoring programs used similar chemical analysis methods; the state programs used different methods.

## Metals

In the upper Bay mainstem, sediment metal concentrations are distributed in a pattern similar to that of fine-grained sediments (i.e., with high silt and clay content), a common finding in many studies. Mainstem sediment metals concentrations are low at the mouth of the Susquehanna River, increasing markedly to the highest concentrations in the region from Pooles Island to the Potomac River mouth which is the area with the highest silt/clay content (Table 37) (Figure 17) [76]. Markedly lower concentrations occur in the mainstem region south of the Potomac River to the Bay mouth. Both the highest sediment concentration gradient and the greatest variability occur in the area from Pooles Island to the Bay Bridge.

More recent sediment contaminants data for the upper mainstem Bay confirm earlier observations that the concentrations of most metals are higher in the northern portion of the mainstem Bay (i.e., above the Potomac River) [278]. Within the middle mainstem Bay, concentrations of metals are higher on the western shore than in the central trough or along the Eastern Shore [76].

When the mainstem sediment metals data are normalized to percentage silt and clay particles in the sediment, the highest average concentrations of most metals occurred in the upper mainstem Bay near the mouth of the Susquehanna River, suggesting that the river is an important source of metal loadings to the sediments in the northern mainstem Bay [76]. Enrichment of metals along the western side of the northern mainstem Bay may be due to metal-enriched sediment carried by the Susquehanna River and transported by the currents moving toward the western shore [151, 292]. Sediments along the Bay's Eastern Shore are carried north from the ocean and often consist of coarser-grained materials [151].

Investigations into the sources of sediment-associated metals to the upper mainstem Bay indicate that both the Susquehanna River and

shoreline erosion are dominant inputs of trace metals to the sediments [148]. Sinex and Helz [279] and Sinex and Wright [280] reported that Baltimore Harbor acts as a sediment trap retaining most of the trace metals originating from the Patapsco River estuary. Both sets of investigators also indicated that there is only minimal down Bay transport of metals from upper mainstem Bay sediments. Sinex and Helz [278] stated that shoreline erosion is the dominant source of sediment to the middle mainstem Bay, however, the relative importance of river transport of sediment from the Potomac, Rappahannock, York, and James rivers compared to shoreline erosion or continental shelf sources is unknown.

The sediment metal concentrations in the Back River and the Patapsco River were substantially higher than those observed elsewhere in the Bay mainstem and tidal tributaries with the exception of some sections of the Elizabeth River (Table 38) [76]. Sediment contaminant concentrations in the Back River were comparable to or higher than sediment concentrations at stations in Baltimore Harbor, except for chromium. Four of the eight metals—arsenic, chromium, lead, and zinc—measured at the Back River station were above their respective PEL values; average concentrations of chromium, lead, and zinc exceeded their respective PEL values at some or all of the Baltimore Harbor stations. Sediment concentrations of zinc and/or lead exceeded their respective PEL values in the eastern, southern and western branches of the Elizabeth River. Sediment concentrations of metals were higher in the Anacostia River than the adjacent upper Potomac and comparable to those in the Back, Patapsco, and Elizabeth rivers. Concentrations of lead and zinc at some of the Anacostia River stations exceeded their respective PEL values.

Outside of the Anacostia, Back, Elizabeth, and Patapsco rivers, the highest sediment metal concentrations tended to be located in the tributaries flowing into the upper mainstem Bay on the upper western, northwestern, and northeastern shores of the mainstem Bay from the Rhode River

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

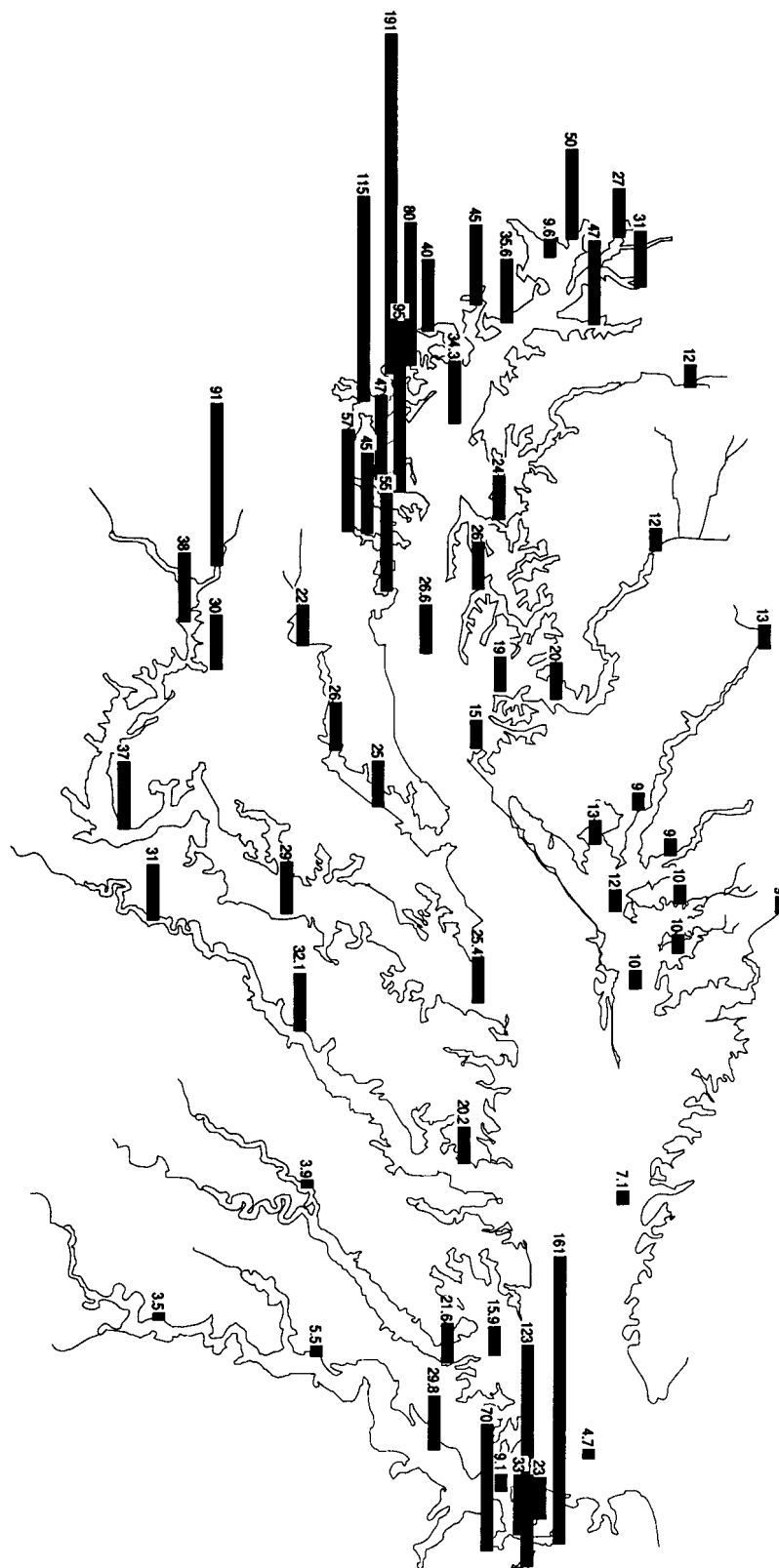
**Table 37.** Sediment concentrations of Chesapeake Bay Toxics of Concern metals in the Chesapeake Bay mainstem and the mouths of major tributaries<sup>1</sup>.

Mainstem Bay/ Tributary Mouth	Data Source <sup>2</sup>	Cadmium	Chromium	Copper	Lead	Mercury
—	PEL Value <sup>3</sup>	7.5	240	270	116	1.4
National Median	NOAA (330)	0.22	80	16	20	0.07
Baywide Median	NOAA (19)	0.44	68	34	39	0.093
Baywide Median	EMAP (60)	0.32	48	20	21	0.12
Baywide Median	MDE (89)	0.60	47	30	38	0.099
Susquehanna to Sassafras	MDE (3)	0.14-0.2 0.2	3.5-23.2 23	3.7-20.5 4.6	12.7-42.1 15.0	0.006-0.1 0.05
Sassafras to Gunpowder	MDE (6)	0.13-1.2 0.7	20.6-36.1 27	30.9-41 35.2	32-66 48.3	0.05-0.6 0.14
Gunpowder to Bay Bridge	MDE (15)	0.01-2.9 0.5	8.9-62.8 38.4	4.6-56 33.6	15-86 51.2	0.02-0.8 0.10
Bay Bridge to Patuxent	MDE (29)	0.01-2.9 0.5	9.5-62 36	2.5-48 29.0	11.5-76 35	0.007-0.6 0.08
Patuxent to Rappahannock	MDE, VADEQ (10)	0.01-1.3 0.6	16-49 35.5	6-30 21.1	6.2-46 28	0.04-0.4 0.05
Rappahannock to James	VADEQ (4)	0.09-0.2 0.2	12-39 19.3	3.4-9 8	6.9-25 11.8	0.025-0.1 0.07
James to Bay Mouth	VADEQ (2)	0.2-0.2 0.2	5.3-23 14.2	2.1-7.2 4.7	5.3-25 15.2	0.086-0.1 0.09
Mouth of Potomac	MDE (3)	0.01-2.4 2.0	29.9-39 35.2	21.6-29 25.5	26.8-35.8 35	0.04-0.4 0.05
Mouth of Rappahannock	VADEQ (2)	0.3-0.4 0.4	35.2-46 40.6	19-21.3 20.2	22-25 23.5	0.1-0.1 0.1
Mobjack Bay	VADEQ (2)	0.15-0.3 0.2	37.3-43 40.2	15.9-17 14.8	17.3-35 26.2	0.072-0.1 0.09
Mouth of York	VADEQ (2)	0.29-0.3 0.3	32.9-56 44.5	20-23.1 21.6	18-35 26.5	0.08-0.1 0.09
Mouth of James	VADEQ (2)	0.3-0.3 0.3	1.6-43 22.3	2.2-16 9.1	1.6-40 20.8	0.046-0.1 0.07

1. Metal concentrations are in µg/g (i.e., ppm) on a dry weight basis; concentration ranges and medians are shown.
2. Total number of samples is in parentheses.
3. Probable Effects Level (MacDonald 1993).

Sources: NOAA - National Oceanic and Atmospheric Administration 1991; EMAP - Weisberg et al. 1992; MDE - Eskin et al. 1994; VADEQ - Eskin et al. 1994.

## Copper Concentrations in Chesapeake Bay Sediments



**Figure 17.** Mean concentrations of copper (ug/g) in Chesapeake Bay mainstem and tributary sediments: 1984-1991. Source: Eskin et al. 1994.

**Table 38.** Sediment concentrations of Chesapeake Bay Toxics of Concern metals from regions of Chesapeake Bay with elevated levels of sediment contamination<sup>1</sup>.

Region	Data Source <sup>2</sup>	Cadmium	Chromium	Copper	Lead	Mercury
—	PEL Value <sup>3</sup>	7.5	240	270	116	1.4
National Median	NOAA (330)	0.22	80	16	20	0.07
Baywide Median	NOAA (19)	0.44	68	34	39	0.093
Baywide Median	EMAP (60)	0.32	48	20	21	0.12
Baywide Median	MDE (89)	0.60	47	30	38	0.099
Baltimore Harbor	NOAA (3)	1.8-3.9	470-540	200-270	130-220	0.66-0.80
	EMAP (3)	0.9-1.1	340-1200	210-220	110-210	0.18-0.26
	MDE (9)	0.01-2.6/1	123-638/300	57-191/112	47-190/115	0.11-0.69/0.39
Back River	NOAA	ND <sup>4</sup>	ND	ND	ND	ND
	EMAP (2)	4.9-6	350-370	220-230	170-190	1.1-1.2
	MDE (1)	3.2-4.6/4.1	238-335/265	167-224/191	176-223/191	0.1-0.7/0.5
Anacostia River	NOAA	ND	ND	ND	ND	ND
	EMAP (1)	1.8	120		150	0.27
	ICPRB (8)	0.92-3.2/1.9	90-155/116	64-126/92	83-410/178	0.29-1/0.49
Elizabeth River	NOAA (3)	0.66-1.4	43-98	46-170	60-180	0.26-0.83
	EMAP (2)	0.81	48-72	20-220	30-190	0.23-0.47
	VADEQ (7)	0.6-6.3/2.6	28-76/51	23-229/96	38-300/137	0.08-1.25/0.5

1. Metal concentrations are in µg/g (i.e., ppm) on a dry weight basis; concentration ranges (and medians where available) are shown.
2. Total number of samples in parentheses.
3. Probable Effects Level (MacDonald 1993).
4. ND = no data available.

Sources: NOAA - National Oceanic and Atmospheric Administration 1991; EMAP - Weisberg et al. 1992; MDE - Eskin et al. 1994; ICPRB - Velinsky et al., 1992, VADEQ - Eskin et al. 1994.

to the Sassafras River (Table 39) [76]. Intermediate concentrations were found in the Patuxent, Potomac, Choptank, and Chester rivers and the embayments along the middle reach of the Eastern Shore. The lowest sediment metals concentrations were observed in tributaries and embayments of the lower Eastern Shore's tributaries and in the Rappahannock, York, and James rivers.

Zinc concentrations tend to be high throughout most of the Chesapeake Bay with the zinc PEL value exceeded in the South, Severn, Magdohy, Middle, Northeast, and James rivers in

addition to the upper and middle mainstem Bay [76]. Sinex and Wright [280] reported that zinc concentrations at deeper depths in sediment cores were not enriched above crustal composition, suggesting anthropogenic sources of the more recent high zinc sediment concentrations. Sediments in the Patuxent, Northeast, and Sassafras rivers had metals concentrations exceeding the arsenic PEL value [76].

Throughout all areas of the mainstem Bay and tidal tributaries, sediment concentrations of several metals were found in the range at which adverse effects were possible but not likely—

**Table 39.** Sediment concentrations of Chesapeake Bay Toxics of Concern metals in Chesapeake Bay tidal tributaries<sup>1</sup>.

Region	Data Source <sup>2</sup>	Cadimium	Chromium	Copper	Lead	Mercury
—	PEL Value <sup>3</sup>	7.5	240	270	116	1.4
National Median	NOAA (330)	0.22	80	16	20	0.07
Baywide Median	NOAA (19)	0.44	68	34	39	0.093
Baywide Median	EMAP (60)	0.32	48	20	21	0.12
Baywide Median	MDE (89)	0.60	47	30	38	0.099
Northwest Rivers <sup>5</sup>	MDE (13)	0.01-1.4 0.5	46-86 69	34-95 69	33.9-129 54	0.099-0.36 0.23
Western Rivers <sup>6</sup>	MDE (27)	0.01-2.1 0.8	60-172 103	35-112 51	17.1-101 58	0.038-0.31 0.16
Patuxent River	MDE (15)	0.01-3.5 1.5	51-120 68	12-34 23	8-52 29	0.038-0.11 0.06
Potomac River	MDE (19)	0.18-2 0.7	36-62 45	28-43 36	14.9-73 33	0.05-0.31 0.15
Rappahannock River	—	ND <sup>4</sup>	ND	ND	ND	ND
York River	—	ND	ND	ND	ND	ND
James River	VADEQ (29)	0.2-6 0.69	5-136 26	3-263 38	6-343 43	0.08-4.66 0.38
Northeast Rivers <sup>7</sup>	MDE (20)	0.01-1 0.5	30-158 64	14-61 42	20-72 44	0.05-0.36 0.17
Chester and Choptank Rivers	MDE (19)	0.01-1.6 0.4	15-76 40	3-31 15	2-55 29	0.034-0.15 0.07
East Bays <sup>8</sup>	MDE (16)	0.1-1.2 0.5	23-56 36	12-32 17	0.7-43 21	0.047-0.11 0.05
Southeastern Rivers and Bays <sup>9</sup>	MDE (52)	0.1-2.9 0.5	6-79 29	3-22 11	0.1-42 15	0.009-0.18 0.05

1. Metal concentrations are in µg/g (i.e., ppm) on a dry weight basis.

2. Total number of samples in parentheses.

3. Probable Effects Level (MacDonald 1993).

4. ND = no data available.

5. Bush, Gunpowder, and Middle rivers.

6. Magothy, Severn, South, Rhode, and West rivers.

7. Northeast, Bohemia, Elk, and Sassafras rivers.

8. Eastern Bay, Choptank Embayment, and Little Choptank River.

9. Fishing Bay, Tangier Sound, Pocomoke Sound, Nanticoke, Wicomico, Manokin, Big Annemessex, and Pocomoke rivers.

Sources: NOAA - National Oceanic and Atmospheric Administration 1991; EMAP - Weisberg et al. 1992; MDE - Eskin et al. 1994; VADEQ - Eskin et al. 1994.

between the NOEL and PEL values [76]. As metals are a natural component of sediment, one method for separating natural concentrations from anthropogenic-influenced concentrations is to “normalize” to a conservative element such as aluminum or iron. By normalizing concentrations, estimates of anthropogenic enrichment of sediment metal concentrations can be made.

Sinex and Helz [278], Sinex and Wright [280], and Eskin et al. [76] all found evidence for widespread sediment enrichment of zinc. Sinex and Helz [278] and Sinex and Wright [280] also found evidence of widespread lead enrichment. More recently, however, Eskin et al. [76] found no evidence of widespread lead enrichment. All three studies documented that Baltimore Harbor was enriched with chromium, with Sinex and Helz [278] presenting evidence for Baltimore Harbor enrichment with cadmium and zinc as well. Sinex and Wright [280] found enrichment of upper mainstem Bay sediments with copper and enrichment with zinc in the lower mainstem Bay sediments.

Eskin et al. [76] presented evidence for enrichment of arsenic (Sassafras River), cadmium (Back River, upper Patuxent River, and mainstem Bay), chromium (Baltimore Harbor and Sassafras River), copper (Baltimore Harbor, Back, Middle, Magothy, and Sassafras rivers), lead (Baltimore Harbor, Back River, Middle River, and upper mainstem Bay), mercury (Baltimore Harbor, Back River, and Sassafras River), nickel (Back, Northeast, and Sassafras rivers, and upper mainstem Bay), and zinc (Back and Magothy rivers). Velinsky et al. [307] reported enrichment of cadmium, lead, and zinc in the Anacostia and upper tidal Potomac rivers. Widespread sediment enrichment, as observed by Eskin et al. [76] for arsenic, cadmium, and zinc, could indicate atmospheric sources as suggested by Sinex and Wright [280]. Helz et al. [147, 148] attributed enrichment of copper, lead, and zinc in surficial sediments to atmospheric deposition.

### Polycyclic Aromatic Hydrocarbons

Sediment polycyclic aromatic hydrocarbon concentrations peak in the mainstem Bay from just south of the Susquehanna Flats to the Chesapeake Bay Bridge (Table 40; Figure 18) [24, 76, 292]. Within the tidal tributaries, the Elizabeth, Anacostia, Patapsco and Sassafras rivers are distinguished by much higher concentrations of polycyclic aromatic hydrocarbons than the other tributaries (Table 41). Some of the other upper western (Middle, Back, Magothy, and Severn rivers) and upper Eastern Shore (Northeast River) tributaries show relatively high concentrations of some polycyclic aromatic hydrocarbons (Table 42). Concentrations of some polycyclic aromatic hydrocarbons were also relatively high in the tidal fresh Potomac River [76]. Bieri et al. [24] observed that summed chemical contaminant concentrations in the mouths of the Patuxent, Potomac, Rappahannock, York, and James rivers tended to be higher than concentrations in most of the mainstem and Eastern Shore sediments. Sediment concentrations of most polycyclic aromatic hydrocarbons were much lower in the embayments and rivers on the lower eastern shore than in any other regions.

All mainstem Bay stations had average polycyclic aromatic hydrocarbon concentrations that were not sufficiently high to be associated with probable adverse effect—all concentrations were less than their respective PEL values [76]. Sediment concentrations of some polycyclic aromatic hydrocarbons in the mainstem region from Turkey Point to the Patapsco River were within the range of concentrations where adverse effects are possible but not likely (i.e., between the NOEL and PEL values).

Sediment concentrations of a number of polycyclic aromatic hydrocarbons exceeded their respective PEL values in the Anacostia, upper Potomac, and Elizabeth rivers and Baltimore Harbor. Average polycyclic aromatic hydrocarbon concentrations at all remaining tributary stations were below the respective PEL values,



# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

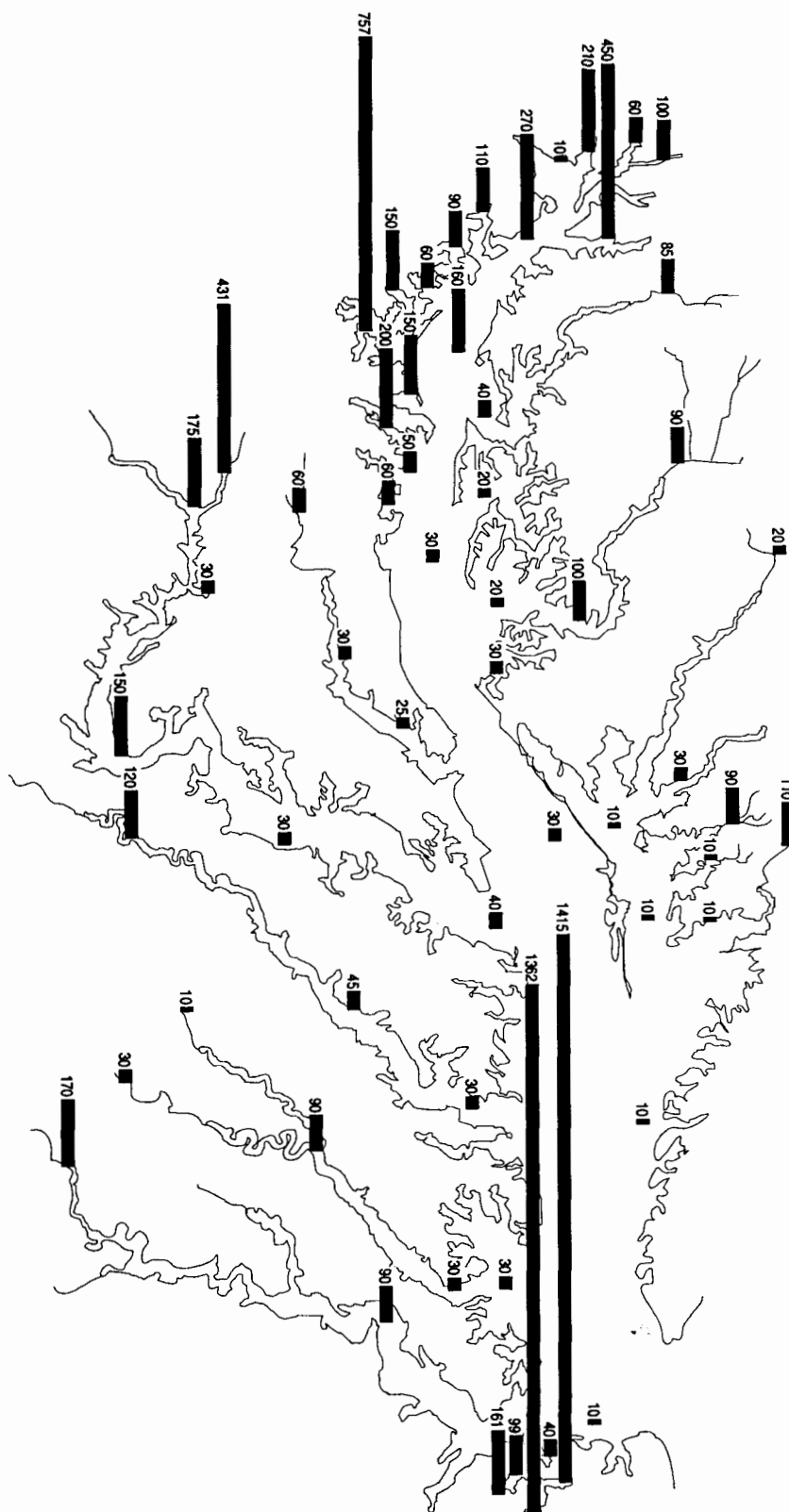
**Table 40.** Sediment concentrations of Bay Toxics of Concern organic compounds in the Chesapeake Bay mainstem and the mouths of major tributaries<sup>1</sup>.

Region	Data Source <sup>2</sup>	Total PCBs <sup>4</sup>	Total Chlordane <sup>5</sup>	Total DDT <sup>6</sup>	Benzo[a] anthracene	Benzo[a] pyrene	Chrysene	Fluoranthene	Napthalene
—	PEL Value <sup>3</sup>	260	—	270	1300	1700	1700	3200	1100
National Median	NOAA (330)	19	0.51	2.8	2.3	19	30	49	7
Baywide Median	NOAA (19)	25	0.93	3.6	38	42	56	99	16
Baywide Median	EMAP (60)	ND <sup>7</sup>	ND	ND	15	37	20	20	13
Baywide Median	MDE (89)	8 <sup>8</sup>			32	35	47	70	7
Susquehanna to Sassafras	MDE (3)	— 8.1	— <0.01	2.5-2.5 2.5	4-30 12	2-30 9	10-70 19	26-80 43	6.7-20 15
Sassafras to Gunpowder	MDE (6)	7.0-12.8 9.9	— <0.01	3.1-5.1 4.1	107-310 208	270-270 270	197-360 279	280-460 371	105-130 120
Gunpowder to Bay Bridge	MDE (15)	10.3-15.5 11.2	— 0.88	3.4-4.8 4.35	80-180 113	71-170 130	112-300 182	211-470 337	7-240 74
Bay Bridge to Patuxent	MDE (29)	— 0.8	— <0.01	0.17-0.30 0.24	1-60 50	3-70 32	13-100 93	12-190 90	3-40 15
Patuxent to Rappahannock	MDE, VADEQ (10)	— 0.1	— <0.01	0.16-0.17 0.17	2-30 12	5-60 21	3-50 26	6-70 31	0.2-20 5
Rappahannock to James	VADEQ (4)	— <0.02	— <0.01	0.17-0.17 0.17	0.4-10 2	1-10 3	1-20 4	2-20 4	0.4-4 1
James to Bay Mouth	VADEQ (2)	— 0.5	— <0.01	0.17-0.17 0.17	2-10 3	2-10 3	4-10 6	5-20 9	2-3 2
Mouth of Potomac	MDE (3)	— 8.3	— <0.01	2.60-2.60 2.60	25-30 28	35-40 37	48-51 51	74-90 88	11-30 13
Mouth of Rappahannock	VADEQ (2)	— 0.5	— <0.01	0.17-0.17 0.17	16-30 21	19-30 30	29-40 33	51-60 54	5-10 7
Mobjack Bay	VADEQ (2)	— <0.02	— <0.01	0.74-0.74 0.74	16-30 21	21-40 32	30-40 34	44-60 51	2-4 3
Mouth of York	VADEQ (2)	— 2.2	— <0.01	1.20-1.20 1.20	17-30 22	19-40 30	34-40 36	54-60 58	1-10 4
Mouth of James	VADEQ (2)	— <0.02	— <0.01	0.17-0.17 0.17	2-140 20	3-130 21	4-170 33	10-420 53	1-10 4

1. Organic concentrations are in ng/g (i.e., ppb) on a dry weight basis.
2. Total number of samples in parentheses.
3. Probable Effects Level (MacDonald 1993).
4. Total PCBs are the sum of PCBs at each level of chlorination.
5. Total chlordane is the sum of the alpha + gamma + cis-chlordane, transchlordane, heptachlordane, and heptachlorepoide for NOAA and EMAP data, but only the sum of alpha + gamma-chlordane for MDE and VADEQ data.
6. Total DDT is the sum of DDE, DDD, and DDT (both o + p forms). Reported VADEQ total DDT concentrations may be over estimates due to co-elution of some chlordane and PCB isomers with p-DDT.
7. ND = no data available.
8. Baywide median value for total PCBs is based on mainstem Bay data only.

Sources: NOAA - National Oceanic and Atmospheric Administration 1991; EMAP - Weisberg et al. 1992; MDE Eskin et al. 1994; VADEQ - Eskin et al. 1994.

## Benzo[a]pyrene Concentrations in Chesapeake Bay Sediments



**Figure 18.** Mean concentrations of benzo[a]pyrene (ng/g) in Chesapeake Bay mainstem and tributary sediments: 1984-1991. Source: Eskin et al. 1994.

**Table 41.** Sediment concentrations of Chesapeake Bay Toxics of Concern organic compounds from regions of Chesapeake Bay with elevated levels of sediment contamination<sup>1</sup>.

Region	Data Source <sup>2</sup>	Total PCBs <sup>4</sup>	Total Chlordane <sup>5</sup>	Total DDT <sup>6</sup>	Benzo[a] anthracene	Benzo[a] pyrene	Chrysene	Fluoranthene	Napthalene
—	PEL Value <sup>3</sup>	260	-	270	1300	1700	1700	3200	1100
National Median	NOAA (330)	19	0.51	2.8	2.3	19	30	49	7
Baywide Median	NOAA (19)	25	0.93	3.6	38	42	56	99	16
Baywide Median	EMAP (60)	ND <sup>7</sup>	ND	ND	15	37	20	20	13
Baywide Median	MDE (89)	8	ND	22	32	35	47	70	7
Baltimore Harbor	NOAA (3)	470-820	6.1-11	28-31	500-650	630-670	800-1700	1100-1900	480-1100
	EMAP (3)	9-82	0.31-1.5	1.9-6.4	15-180	58-230	510-210	86-450	220-410
	MDE (9)	<5.7	<1.33-7.5	<5.7-22.3	90-2100/504	120-3000/685	510-290/223	140-4100/993	130-350/224
Back River	NOAA	ND	ND	ND	ND	ND	ND	ND	ND
	EMAP (2)	42-460	<2.4 <sup>8</sup>	8.8-47	380	260	520	690	270
	MDE (1)	ND	22.4	<5.7	178-281/230	152-153/152	374	431-498/465	175
Anacostia River	NOAA	ND	ND	ND	ND	ND	ND	ND	ND
	EMAP (1)	40	9.6	6.2	160	89	260	340	14
	ICPRB (8)	210-2200	29-120	28-140	169-607/397	212-586/431	253-817/595	482-1867/1265	30-130/58
Elizabeth River	NOAA (3)	90-240	3-3.4	6.6-23	130-1500	130-2800	300-2800	280-2800	130-600
	EMAP (2)	<110	<4.1	<11	38-450	7-540	410-660	67-980	27-180
	VADEQ (7)	19-2400/354	ND	ND	36-2030/624	34-2520/759	54-3770/989	92-6029/1876	3-490/163

1. Organic concentrations are in ng/g (i.e., ppb) on a dry weight basis.
2. Total number of samples is in parentheses.
3. Probable Effects Level (MacDonald 1993).
4. Total PCBs is the sum of PCBs at each level of chlorination.
5. Total chlordane is the sum of alpha + gamma + cis - chlordane, trans-nonachlor, heptachlor, and heptachlorepoide for NOAA, EMAP and ICPRB data, but only the sum of alpha + gamma - chlordane for MDE data.
6. Total DDT is the sum of DDE, DDD, and DDT both o+p forms. Reported total DDT concentrations maybe overestimated due to co-elution of some chlordane and PCB isomers with the p-DDT.
7. ND = no data available.
8. < = less than detected limit.

Sources: NOAA - National Oceanic and Atmospheric Administration 1991; EMAP - Weisberg et al. 1992; MDE - Eskin et al. 1994; ICPRB - Velinsky et al. 1992, VADEQ - Eskin et al. 1994.

**Table 42.** Sediment concentrations of Chesapeake Bay Toxics of Concern organic compounds in Chesapeake Bay tidal tributaries<sup>1</sup>.

Region	Data Source <sup>2</sup>	Total PCBs <sup>4</sup>	Total Chlordane <sup>5</sup>	Total DDT <sup>6</sup>	Benzo[a] anthracene	Benzo[a] pyrene	Chrysene	Fluoranthene	Napthalene
—	PEL Value <sup>3</sup>	260	—	270	1,300	1,700	1,700	3,200	1,100
National Median	NOAA (330)	19	0.51	2.8	2.3	19	30	49	7
Baywide Median	NOAA (19)	25	0.93	3.6	38	42	56	99	16
Baywide Median	EMAP (60)	ND <sup>8</sup>	ND	ND	15	37	20	20	13
Baywide Median	MDE (89)	8 <sup>7</sup>			32	35	47	70	7
Northwest Rivers <sup>9</sup>	MDE (13)	<5.7	<1.33	<	23-200 133	91-170 135	— 368	24-600 290	528
Western Rivers <sup>10</sup>	MDE (27)	6.6-26.5	<1.33-6	< -26.5	21-360 97	17-300 91	41-590 154	57-780 348	40-370 134
Patuxent River	MDE (15)	<5.7-12.2	<1.33-3.3	< -12.2	20-50 28	23-80 34	47-60 55	34-110 64	11-30 11
Potomac River	MDE (19)	<5.7-13	<1.33	< -8.9	14-230 75	11-190 70	23-300 109	32-360 105	14-50 18
Rappahannock River	VADEQ (14)	0.6	<	0.3	3-180 24	3-170 33	7-180 40	8-200 63	<-10 2
York River	VADEQ (19)	<	<	11.2	4-210 35	4-50 28	9-120 54	13-170 79	<-600 5
James River	VADEQ (15)	21.3	<	0.7	< -150 47	5-170 69	1-260 76	1-330 100	<-30 7
Northeastern Rivers <sup>11</sup>	MDE (20)	<	<1.33	<	30-144 120	40-660 137	104-1,530 169	80-1,130 241	98-370 149
Chester and Choptank Rivers	MDE (19)	< -11	<1.33-1.5	<	22-130 47	15-120 75	33-240 98	61-220 83	21-150 44
East Bays <sup>12</sup>	MDE (16)	< -0.43	<1.33-2.3	<	1-20 13	2-40 15	15-30 24	7-60 38	13-50 28
Southeastern Rivers and Bays <sup>13</sup>	MDE (52)	<	<1.33	< -21.2	5-130 11	2-110 12	7-230 18	4-320 20	2-10 5

- Organic concentrations are in ng/g (i.e., ppb) on a dry weight basis.
  - Total number of samples in parentheses.
  - Probable Effects Level (MacDonald 1993).
  - Total PCBs are the sum of PCBs at each level of chlorination.
  - Total chlordane is the sum of the alpha + gamma + cis-chlordane, trans-nonachlor, heptachlor, and heptachlorepoide for NOAA and EMAP data, but only the sum of alpha + gamma-chlordane for MDE and VADEQ data.
  - Total DDT is the sum of DDE, DDD, and DDT (both o + p forms). Reported VADEQ total DDT concentrations may be overestimates due to co-elution of some chlordane and PCB isomers with p-DDT.
  - ND = no data available.
  - Baywide median value for total PCBs is based on mainstem Bay data only.
  - Bush, Gunpowder, and Middle rivers.
  - Magothy, Severn, South, Rhode, and West rivers.
  - Northeast, Bohemia, Elk, and Sassafras rivers.
  - Eastern Bay, Choptank Embayment, and Little Choptank River.
  - Fishing Bay, Tangier Sound, Pocomoke Sound, Nanticoke, Wicomico, Manokin, Big Annemessex, and Pocomoke rivers.
- Sources: NOAA - National Oceanic and Atmospheric Administration 1991; EMAP - Weisberg et al. 1992; MDE Eskin et al. 1994; VADEQ - Eskin et al. 1994.

therefore, adverse effects are not probable. Maximum concentrations of a number of polycyclic aromatic hydrocarbons were observed, however, between the NOEL and PEL values in the upper western shore tributaries (from the West River to the Middle River), and the Sassafras, Potomac, Rappahannock, York, and James rivers [76].

### **Polycyclic Biphenyls**

One or more PCB congeners were detected in sediments throughout much of the mainstem Bay and tidal tributaries, generally at very low concentrations. The maximum measured concentrations were all below the NOEL value with the exception of one sample in the James River (Tables 40 and 42). Sediment concentrations of PCBs were higher in the upper mainstem Bay compared to the rest of the mainstem Bay [76]. In the eastern and southern branches of the Elizabeth River and in the Anacostia River, sediment concentrations of total PCBs were above the PEL value and, therefore, are likely to be associated with adverse effects on aquatic organisms (Table 41).

### **Pesticides**

DDT was the most commonly detected pesticide in mainstem Bay sediment—some form of DDT was detected at 14 of the 16 stations sampled—with concentrations of all forms of DDT below the NOEL value (Table 40) [76]. Several other pesticides (aldrin, chlordane, dicofol, and nonachlor) were detected at fewer than four mainstem Bay stations at concentrations above which adverse effects are probable [76]. Sediment concentrations of chlordane above values associated with probable adverse effects were observed in the Anacostia River (Table 41). Detectable concentrations of alachlor, carbofuran, various forms of chlordane, chlorpyrifos, cyanazine, DDT, lindane, metolachlor, permethrin, and simazine were observed in the tributary sediments. No pesticide was found at concentrations above which adverse effects are considered probable, although some compounds were found above

concentrations at which adverse effects are thought to be possible [76].

### **TEMPORAL CHANGES**

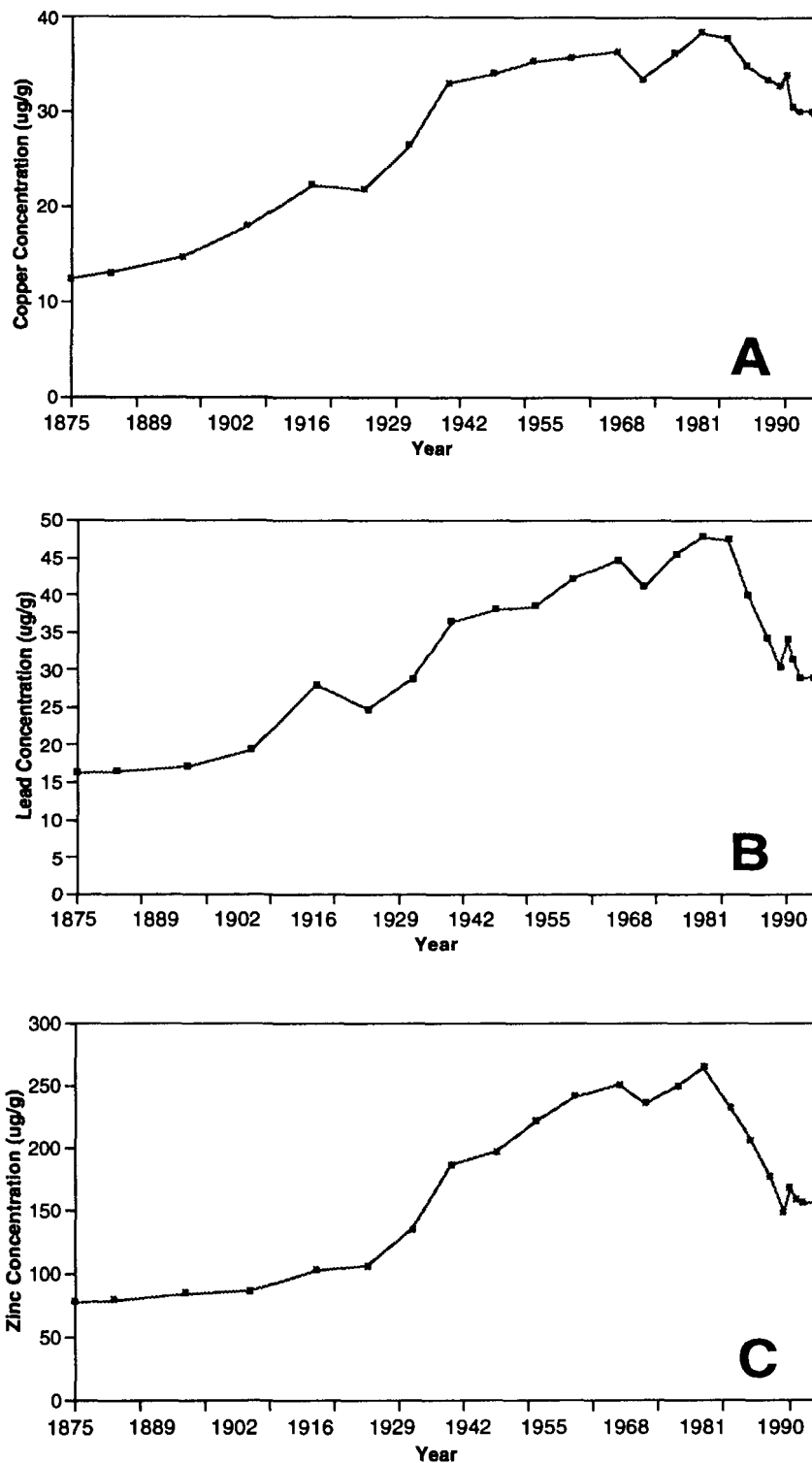
Analysis of sediment cores is useful in evaluating temporal trends of sediment contamination. Scientists use sediment cores to establish long-term trends by finding background or baseline concentrations in the deeper sections of the cores and constructing a chronology of sediment contamination by analyzing the shallower and more recently deposited sediment. With sufficient resolution, the changes in chemical contaminant concentrations can help determine the effectiveness of management control strategies in reducing chemical inputs to the Bay.

### **Metals**

Increased erosion within the Bay watershed due both to deforestation and the introduction of European agricultural techniques with the arrival of the early settlers translated into large increases in sedimentation rates throughout the Bay [31, 32, 33]. Cores collected in the northern mainstem Bay near the Susquehanna River show high concentrations of metals with little variation over time [93]. This uniformity results from the high sedimentation rates, ranging from one to eight centimeters per year, with bioturbation reaching 30 centimeters in some areas. Due to the rapid accumulation rate, these cores were too short to reach sediments untouched by anthropogenic influence.

In contrast, sediment cores obtained further south revealed an increase in metals with time, although the level of overall contamination was lower than those collected in the northern mainstem Bay (see *Spatial Changes* section). In particular, lead, zinc, and copper increase with time in the sediment cores taken near the Choptank River, and lead, zinc, and nickel increase with time in the cores obtained near the Rappahannock River [93]. In cores from the James River taken in 1979, average concentrations of copper, lead, and zinc in surface sediments were

## Metals Concentrations in Middle Chesapeake Bay Sediment Cores



**Figure 19.** Concentrations of copper (A), lead (B), and zinc (C) in sediment cores collected from the middle Chesapeake Bay mainstem. Each figure is displayed showing metal concentrations with increasing depth into the sediment presented as the approximate year that sediment was deposited on the bottom of the Bay. Source: Owens and Cornwell, in review.

twice as high as surface sediments in 1954, reflecting increased inputs over 25 years [336]. Surface sediment enrichments of trace metals were also observed from a series of cores taken in the mainstem Potomac estuary [183].

The available data illustrate the increased input of metals to the Bay sediments in the past 30 to 50 years due to human activity. Also, the various metals appear to have different origins; manganese, iron, cobalt, nickel, and zinc generally come from river discharge, shoreline erosion, atmospheric deposition (zinc), and saltwater advection from the ocean, and human activities. Chromium and copper originate from domestic wastes as well as direct industrial discharge, cadmium comes from waste waters, and lead primarily comes from atmospheric dust and rain [146, 149].

Recent work by Owens and Cornwell [227] reveals clear declines over the past several decades in the concentrations of metals in a core taken from the middle mainstem Bay. Concentrations of copper, lead, and zinc increased from the early 1900s to a broad maximum centered around 1960 to 1970, after which concentrations sharply decreased until the present (Figure 19). Present surface-to-bottom concentration ratios are generally two for these metals, down from ratios of approximately three at the concentration maximum in the mid-1970s.

A comparison of surface sediment data from surveys conducted in 1973 and 1991 in the Patapsco River reveal recent declines in sediment metal concentrations [76]. For the majority of metals analyzed in both surveys, the 1991 average sediment concentrations were approximately 50 percent of the 1973 average concentration (Figure 20). Nickel was the exception to this trend, as its concentration was not dramatically different in the two studies.

Mean sediment concentrations of metals measured in 1991 were generally lower than concentrations measured in 1984 and 1985 in the

mainstem Bay [76]. Arsenic was the only metal to show consistently higher mean sediment concentrations in the mainstem Bay in 1991 compared to the 1984 and 1985 data. Comparisons of mainstem Bay sediment metal concentrations from 1991 with data collected from nearby stations in the late 1970s and early 1980s also shows that concentrations of most metals were lower in 1991. Sediment cadmium concentrations decreased dramatically, while other metals show more modest declines.

### Organic Chemicals

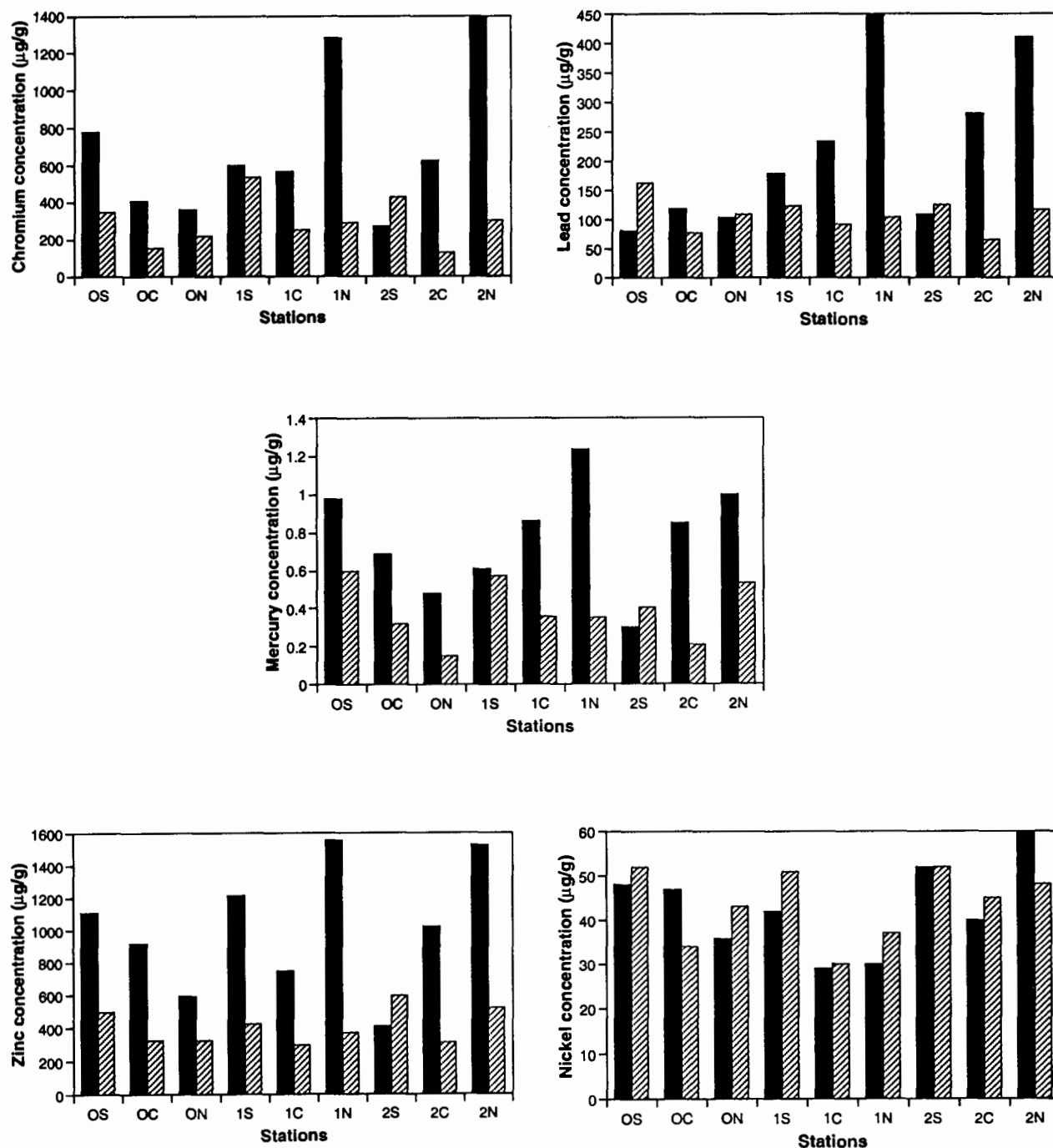
A few studies have been published regarding the historical distribution of organic chemical contaminants in sediment cores collected in Chesapeake Bay [24, 161, 231]. From these studies, the concentrations of organic chemical contaminants such as DDT and its metabolites, other chlorinated pesticides, PCBs, and polycyclic aromatic hydrocarbons appear to have increased over the years—particularly after 1920 to 1930. The maximum concentrations were reached in the late 1970s.

Total polycyclic aromatic hydrocarbon sediment concentrations measured in a sediment core collected from the middle mainstem Bay also illustrate recent declines [9]. The highest sediment concentrations occurred between the 1940s and 1950s. From the late 1950s to the early 1980s, sediment concentrations decreased to approximately one-third of the historical maximum (Figure 21). The near constant values after 1980 may be due to steady inputs of hydrocarbons to the Bay or, alternatively, biological and physical mixing of the upper ten centimeters of the sediment. Trace metal profiles, however, do not reflect such mixing in the near surface sediment of this core.

### FINDINGS AND CONCLUSIONS

Eskin et al. [76] synthesized multiple years of Bay sediment contaminant data and provided an estimate of probable biological significance of observed sediment contaminant concentrations

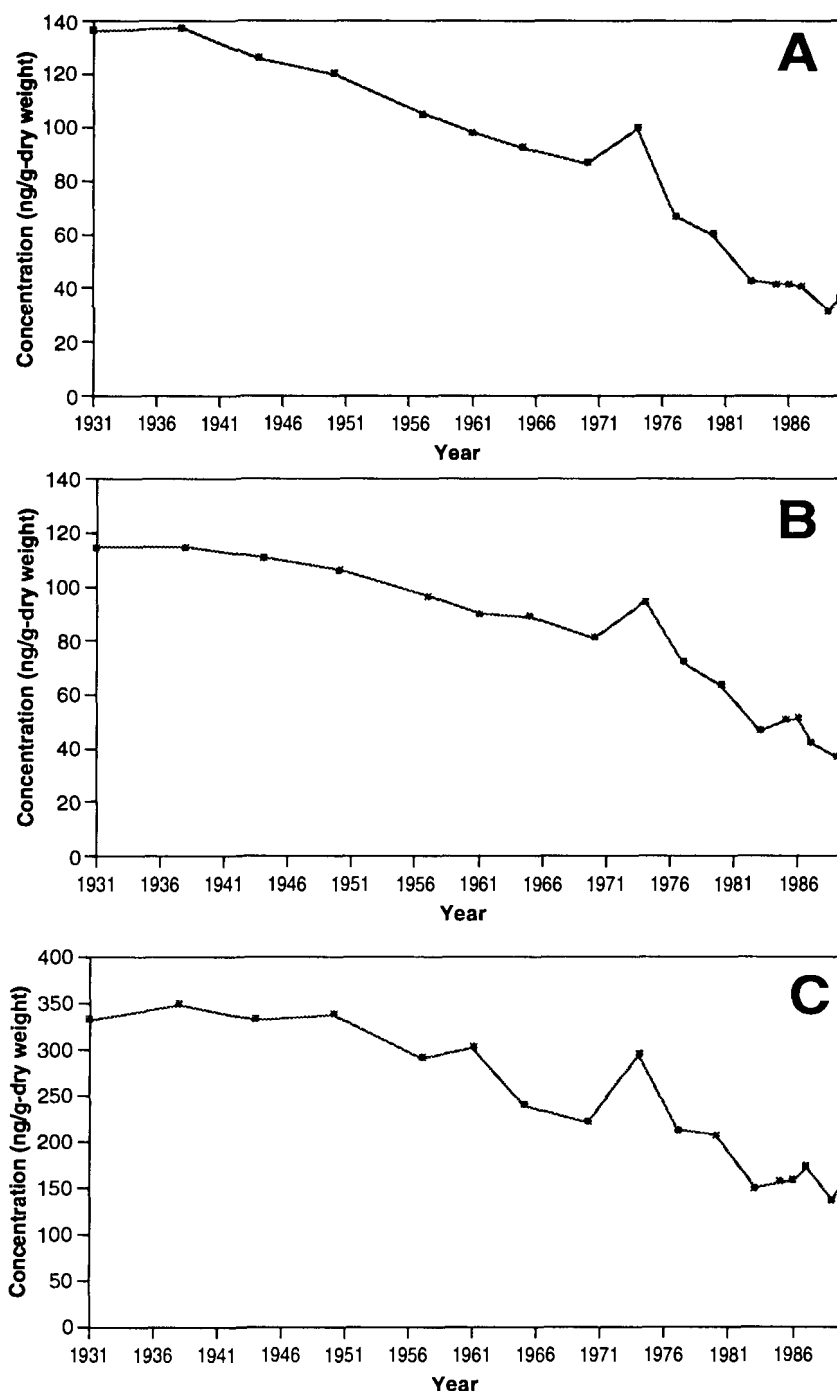
## Metals Concentrations in Patapsco River Sediments



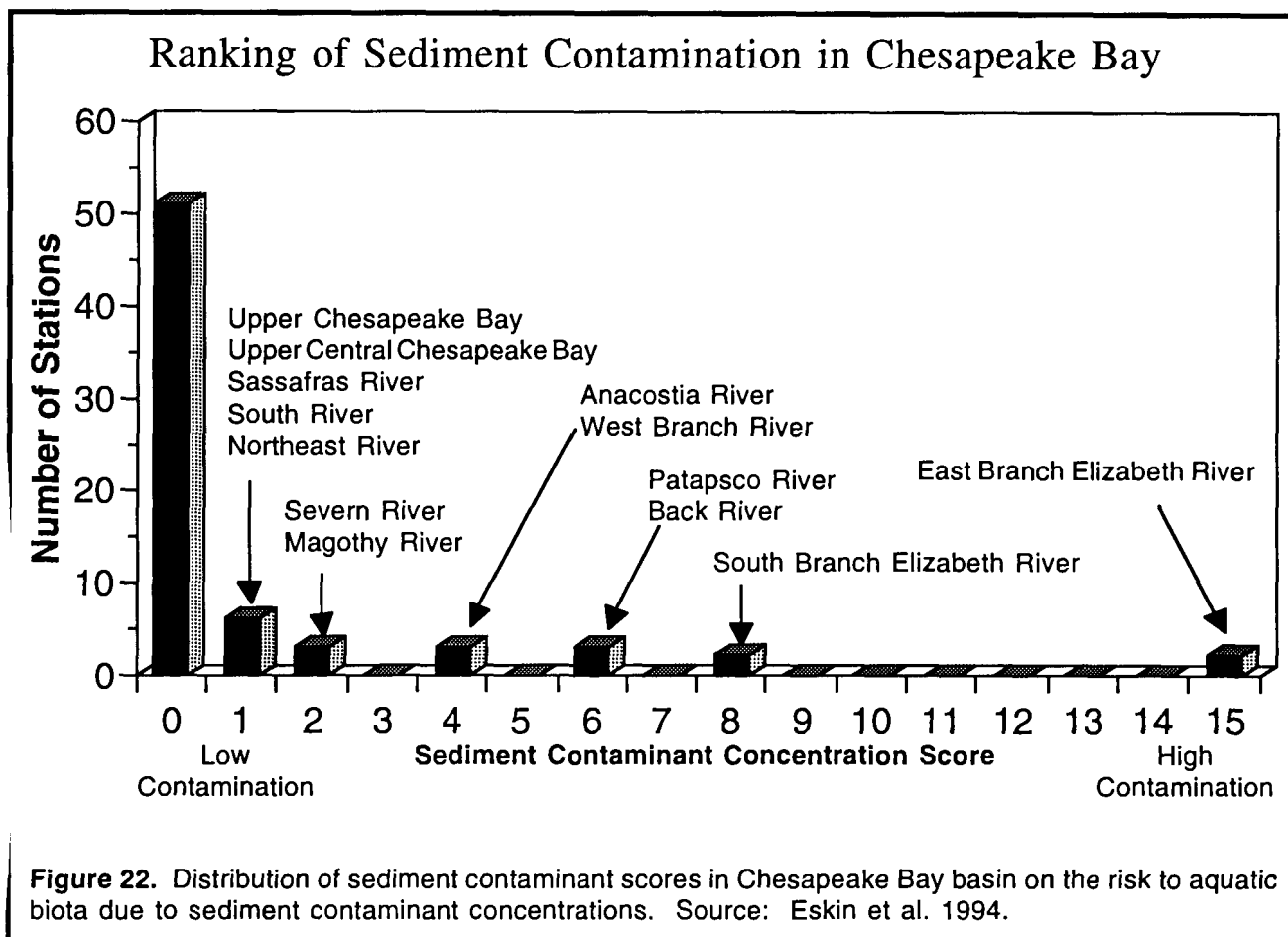
**Figure 20.** Patapsco River sediment metals concentrations for chromium, lead, mercury, nickel, and zinc at stations sampled in 1973 (■) and 1991 (▨). Sources: Villa and Johnson 1974; Eskin et al. 1994.



### Polycyclic Aromatic Hydrocarbon Concentrations in Middle Chesapeake Bay Sediment Cores



**Figure 21.** Concentrations of three Chesapeake Bay Toxics of Concern polycyclic aromatic hydrocarbons – benzo[a]anthracene (A), benzo[a]pyrene (B), and fluoranthene (C) – in sediment cores collected from the middle Chesapeake Bay mainstem. Each figure is displayed showing polycyclic aromatic hydrocarbons concentrations with increasing depth into the sediment presented as the approximate year that sediment was deposited on the bottom of the Bay. Sediments dated back to 1878 had concentrations of benzo[a]anthracene (A), benzo[a]pyrene (B), and fluoranthene (C) of 1.6, 1.9, and 2.7 ng/g, respectively. Source: Baker, unpublished data.



using a ranking procedure. Stations or regions were ranked according to the likelihood that the average concentrations of sediment contaminants at these locations would be associated with adverse effects on aquatic organisms (Figure 22). Based on this ranking and the data summarized above, Eskin et al. [76] concluded:

- A few restricted areas of the Bay which are heavily industrialized and/or urbanized—Baltimore Harbor, Back River, Anacostia River and Elizabeth River—have sediment concen-

trations of many chemical contaminants considered high enough to likely result in adverse effects on aquatic organisms. Estimates of relative risk to aquatic organisms due to sediment contamination in these areas are much higher than those for other areas of the Bay.

- Areas in and near the heavily or rapidly growing areas in the northern and western shores of the Chesapeake Bay have the next highest estimated risk to aquatic organisms from sediment contamination.

**Box 5. Sources of information on Chesapeake Bay sediment contamination**

Chesapeake Bay Ambient Toxicity Assessment Program Reports [110,113,114]  
 Chesapeake Bay Contaminated Sediment Critical Issue Forum Proceedings [48]  
 Chesapeake Bay Sediment Trace Elements [149]  
 Contaminants in Chesapeake Bay Sediments: 1984-1991 [76]  
 Inventory of Chemical Concentrations in Coastal and Estuarine Sediments [66]  
 NOAA National Status and Trends Reports [210,212,213,215,275]  
 State of the Chesapeake Bay - Second Annual Monitoring Report Compendium [180]

- The lowest levels of risk to aquatic organisms due to sediment contamination are found in less populated, rural areas in the southern and eastern portions of the Chesapeake Bay and its tidal tributaries, where data indicate sediment contaminant concentrations should not result in adverse effects on aquatic organisms.
- In most regions, sediment concentrations of metals appear to pose greater risks to aquatic organisms than do sediment concentrations of polycyclic aromatic hydrocarbons. Sediment concentrations of PCBs and pesticides appear to pose an even lesser risk to aquatic organisms outside of the areas with highly contaminated sediments.

Other investigators have documented very localized areas with elevated sediment contaminant concentrations around point source discharges, within marinas, or adjacent to military facility beyond the four areas described above [67, 101].

Results from past and recent sediment core analyses and comparisons of 1991 sediment contaminant concentrations with measurements taken in the late 1970s through the mid-1980s all point towards declining sediment concentrations for most metals, pesticides, and other organic chemical contaminants. These data reflect decreases in the historical sources of chemical contaminants to Bay sediments.

## Effects on Bay Resources

### Ambient Effects

Although numerous types of toxicological data exist, it is difficult to evaluate the extent of chemical contaminant-related effects on the Bay's biota. Highly contaminated areas show these most readily. Outside of urbanized and industrialized areas having severely contaminated

sediments, it is much more difficult to detect the adverse effects that low levels of chemical contaminants may cause.

The difficulty associated with evaluating toxic effects on biota is partly due to the problem of determining what constitutes an adverse effect on cells, individual organisms, or biological communities. Additionally, establishing cause and effect relationships is exceedingly difficult in most cases. Whether chemicals are available to organisms depends on the properties of the chemicals themselves as well as the prevailing natural and manmade conditions. These properties and conditions include factors such as salinity, pH, and temperature as well as the presence or absence of multiple chemical contaminants, disease organisms, or such direct anthropogenic impacts as fishing mortality and habitat loss. Ecological processes such as predation and competition also influence the magnitude of effects.

Changes in the population and community, such as population declines and shifts in species dominance, may result from exposure to chemical contaminants [260, 262, 263]. Assessing these types of changes is fundamentally difficult as linkages between exposure and population effects may be difficult, if not impossible, to document clearly.

Nonetheless, using several approaches, scientists have shown that chemical contaminants in Chesapeake Bay waters and bottom sediments cause adverse effects on organisms in some locations. The majority of this work has focused on a few areas in which large concentrations of human and industrial activity have caused high chemicals loadings and accumulations. Separate studies have documented toxicity outside of these few severely contaminated areas. Findings reported below and summarized in Table 43 are from a comprehensive review article by Wright and colleagues [338] and from the first three years of the Chesapeake Bay Ambient Toxicity Assessment Program [110, 113, 114].

**Table 43.** Summary of Chesapeake Bay ambient effects findings.

REGION	YEARS	OBSERVED EFFECTS	SOURCES
Upper Chesapeake Bay	1985	Striped bass yolk sac larvae and yearlings survival was evaluated at three natural spawning habitats using in-situ test chambers. Three Chesapeake and Delaware Canal sites were evaluated. After 96 hours of exposure to Chesapeake and Delaware Canal habitat water (two experiments) the cumulative percent survival for larvae ranged from 42-59.5%. Although all yearlings survived 10 days of exposure, some sublethal effects were seen: gills showed telangiec tases and reduced vacuolization of hepatocytes.	Hall 1985, Hall et al. 1987a
Upper Chesapeake Bay	1989	<i>In-situ</i> studies were conducted at sites in the upper Chesapeake Bay on prolarval (one 96 hour test) and yearling (one 14 day test and one 27 day test) striped bass. Upper Chesapeake Bay prolarval survival ranged from 6-52%; control survival was >77%. Yearling survival ranged from 10-35%; control survival was 100%. Potentially toxic concentrations of some metals (cadmium, chromium, and copper) were observed in the upper Chesapeake Bay.	Hall et al. 1991b, Hall et al. 1992b
Middle River	1992-1993	Significantly reduced shell development for the coot clam ( <i>Mulinia lateralis</i> ) reported upon exposure to ambient waters.	Hall et al. 1994
Patapsco River	1990	Significant reductions in survival of grass shrimp ( <i>Palaemonetes pugio</i> ) reported upon exposure to ambient water. Survival of amphipods ( <i>Lepidactylus dytiscus</i> ) and polychaete worms ( <i>Streblospio benedicti</i> ) were significantly reduced upon exposure to ambient sediments. The amphipods also showed significant reductions in the ability to rebury after a 20 day exposure to the ambient sediments.	Hall et al. 1991
Patapsco River	1991	Significant reductions in survival and growth of two species of amphipods ( <i>Hyallela azteca</i> , <i>Lepidactylus dytiscus</i> ) reported upon exposure to ambient sediments. Decreased rates of reburial and high numbers of organisms emerging from the sediment or swimming in the overlying waters, indicating an avoidance response, were observed in the ambient sediment toxicity test chambers.	Hall et al. 1992
Patapsco River	1992	The amphipod <i>Leptocheirus plumulosus</i> was used to test the spatial extent and variability of sediment toxicity at sites within the Patapsco River; sediment from the Choptank River served as a control. Sediments from the Bear Creek area were found to be toxic (100% mortality observed on several occasions). Other test sites and control sites had at least 80% survival.	Pinkney and Rzemien 1993
Potomac River, Anacostia River	1986-87	During 1986 and 1987 studies of chlordane and PCB levels in fish tissue with the District of Columbia, fish collected from some sites (lower Anacostia and Potomac rivers) had high incidences of gross lesions.	Block 1990

**Table 43 (con't.)** Summary of Chesapeake Bay ambient effects findings.

REGION	YEARS	OBSERVED EFFECTS	SOURCES
Potomac River	1986	The survival of striped bass prolarvae and yearlings was evaluated for 96 hours and 7 days, respectively, <i>in-situ</i> at three Potomac River locations; water quality analyses were conducted concurrently. Survival of prolarvae and yearlings was significantly reduced: 4.5-22.5% for prolarvae (control survival was >81%) and 0-77% for yearlings (control survival was 100%). Histological evaluations of yearlings showed adverse changes in kidneys. Factors contributing to prolarvae mortality were inorganic contaminants (monomeric aluminum, cadmium, and copper) and sudden low temperature. High pH from a point source and possibly inorganic contaminants were responsible for yearling mortality.	Hall et al. 1986b, Hall et al. 1987e
Potomac River	1989	During the 1989 striped bass spawning season, <i>in-situ</i> prolarval (three 96 hour tests) and yearling (one 27 day test) studies were conducted at three stations in the Potomac River. Prolarval survival in the Potomac ranged from 3-33%, control was >83%, possible die to low water temperatures. Yearling survival in the Potomac ranged from 5% (Maryland site), 80% (middle river site), 30% (Virginia site); control survival was 100%. Low survival was possibly due to elevated levels of chromium (29 µg/l) and arsenic (12 µg/l). Histological and hematological examinations revealed that the Potomac River yearlings had pathology possibly associated with water-borne contaminants.	Hall et al. 1991b, Hall et al. 1992b
Potomac River	1990	Significant reductions in survival of <i>Ceriodaphnia dubia</i> and sheepshead minnow larvae ( <i>Cyprinodon variegatus</i> ) reported upon exposure to ambient waters. Significant reductions in the survival of amphipods ( <i>Lepidactylus dytiscus</i> ) and growth of grass shrimp ( <i>Palaemonetes pugio</i> ) reported upon exposure to ambient sediments.	Hall et al. 1991
Potomac River	1991	Significant reductions in survival of larval sheepshead minnow ( <i>Cyprinodon variegatus</i> ) reported upon exposure to ambient waters. Significant reductions in the survival of amphipods ( <i>Hyalella azteca</i> ) and polychaete worms ( <i>Streblospio benedicti</i> ) and survival and growth of amphipods ( <i>Lepidactylus dytiscus</i> ) upon exposure to ambient sediments.	Hall et al. 1992
Anacostia River	1986	<i>Corbicula</i> collected from the Potomac River (at Rosier Bluff) and placed in trays of sediment collected at either the Anacostia River (Navy Yard) or the Potomac River (Rosier Bluff). One of each tray (Anacostia and Potomac) of sediment and clams was placed in the Anacostia and Potomac rivers for approximately four months. Gonadal tissue and egg measurements were conducted; eggs from all sediment trays developed normally. However, clams on Anacostia sediment had 1/3 the total egg mass. Clams 4-8 mm in length were absent in the trays placed in the Anacostia River, suggesting clam larvae mortality possibly due to toxics in water or sediment.	Phelps 1987

Table 43 (con't.) Summary of Chesapeake Bay ambient effects findings.

REGION	YEARS	OBSERVED EFFECTS	SOURCES
Anacostia River	1987	Sediment samples from the Anacostia River's Kenilworth Marsh were collected and examined for possible toxicity to the growth and reproduction of <i>Corbicula</i> . Clams were placed in trays filled with Kenilworth Marsh sediment and then placed in the Potomac River for 4.5 months. Positive control trays (Potomac River sediment) and negative control trays (Navy yard sediment — Anacostia River) were also placed in the Potomac River. Kenilworth Marsh sediment showed no toxicity; Potomac River sediment was unexpectedly toxic to clam reproduction. In four day sediment bioassay testing, clam larvae in Kenilworth Marsh sediment, Potomac River (at Wilson Bridge) sediment, and Anacostia River (Navy Yard) sediment had 14%, 17%, and 70% mortality respectively.	Phelps and Clark 1988
Anacostia River	1989	Sediment samples were collected from ten Anacostia River sites to determine toxicity to <i>Corbicula</i> larvae. After 96 hours, significant mortalities were observed for individuals exposed to sediment from Fredrick Douglas Bridge (west) and May Yard (west) areas. Intermediate toxicity was observed on individuals exposed to sediment from Pennsylvania Avenue bridge and Benning Road (west).	Phelps 1993
Anacostia River	1991	Sediment samples from the Anacostia River (Navy Yard pier) and control sediment samples from the Potomac River (Fort Foote) were collected to determine if Anacostia River sediment toxicity was correlated with ammonia or sediment contamination. Twenty to thirty <i>Corbicula</i> larvae (from clams collected from the Potomac River) were placed on the sediment for 96 hours. In order to release ammonia, the pH was raised to 9, resulting in high <i>Corbicula</i> mortality (98%) in Navy Yard sediment. It is unknown whether high mortality was due to increased ammonia levels or the pH increase.	Phelps 1991
Elizabeth River	1982	Ware River spot were placed in experimental flowthrough tanks; a) one contained sediments from the Elizabeth River contaminated with polycyclic aromatic hydrocarbons (PAHs); and b) the other contained uncontaminated control sediment from the York River. Within 8 days, spot in the experimental tank (Elizabeth River sediments) developed integumental lesions, fin and gill erosion, and reduced hematocrits with some individuals developing pancreatic and liver alterations; control fish exhibited no effects.	Hargis et al. 1984
Elizabeth River	1983	Macrophage phagocytosis was found to be reduced in spot and hogchoker collected from regions of the Elizabeth River contaminated with PAHs.	Weeks et al. 1986
Elizabeth River	1983	Oysters from the Rappahannock River were transplanted to five sites on the Elizabeth River (26 oysters per site). Twelve oysters were periodically removed from each site for PAHs analysis; PAHs uptake was rapid, indicating bioavailability. Sediment and fish samples were also collected; fish showed gross abnormalities coincident with PAHs in sediment.	Hugget et al. 1987

**Table 43 (con't.)** Summary of Chesapeake Bay ambient effects findings.

REGION	YEARS	OBSERVED EFFECTS	SOURCES
Elizabeth River	1983	Hogchokers and toadfishes collected from areas of the Elizabeth River contaminated with PAHs were found to have fin erosion; cataracts were observed in spot, croaker, and weakfish collected from the same area. Frequency of effects was coincident with contamination. Oysters collected from a clean system were transplanted to the Elizabeth River to evaluate the effects of PAH-contaminated sediment. After nine weeks, tissue residues as high as 60 µg/g were observed in oysters transplanted to the most contaminated sites.	Bender et al. 1988
Elizabeth River	1983-84	When experimentally exposed to effluents from sediments contaminated with PAHs, spot developed lens cataracts, fin rot, and skin ulcerations. Fish (spot, weakfish, Atlantic croaker) collected from contaminated sites had cataracts, some had fin rot. The highest evidence was coincident with heavy PAH contamination.	Hargis and Zwerne 1988 a,b
Elizabeth River	1983-84	Mummichog collected from an area of the Elizabeth River contaminated with PAHs were found to have a high incidence of idiopathic hepatic lesions. In 93% of the collected fish grossly visible hepatic lesions were present; 33% had hepatocellular carcinomas. Fish collected from two reference sites did not have hepatic lesions.	Vogelbein et al. 1990
Elizabeth River	1984	Spot and hogchoker collected from regions of the Elizabeth River heavily contaminated with PAHs were found to have reduced macrophage phagocytosis. When the fish were held in clean water, macrophage phagocytic activity returned to normal.	Weeks and Warriner 1984
Elizabeth River	1985	Young of the year spot collected from an areas of the Elizabeth River contaminated with PAHs were found to have higher levels of the substrate-inducible enzymes aryl hydrocarbon hydroxylase (AHH) and superoxide dismutase (SOD) when compared to fish from reference sites. Increases in SOD are the result of increases in toxic oxidation products, like those involved in the metabolism of PAHs by AHH.	Roberts et al. 1987
Elizabeth River	1988	Preliminary findings of a study suggest that spot and hogchoker responses to exposure to PAH contaminated sediment (either invivo or invitro) resulted in distinct suppression of luminol-dependent chemiluminescence (used to measure macrophage response) suggesting that macrophages were reduced.	Warriner et al. 1988

**Table 43 (con't.)** Summary of Chesapeake Bay ambient effects findings.

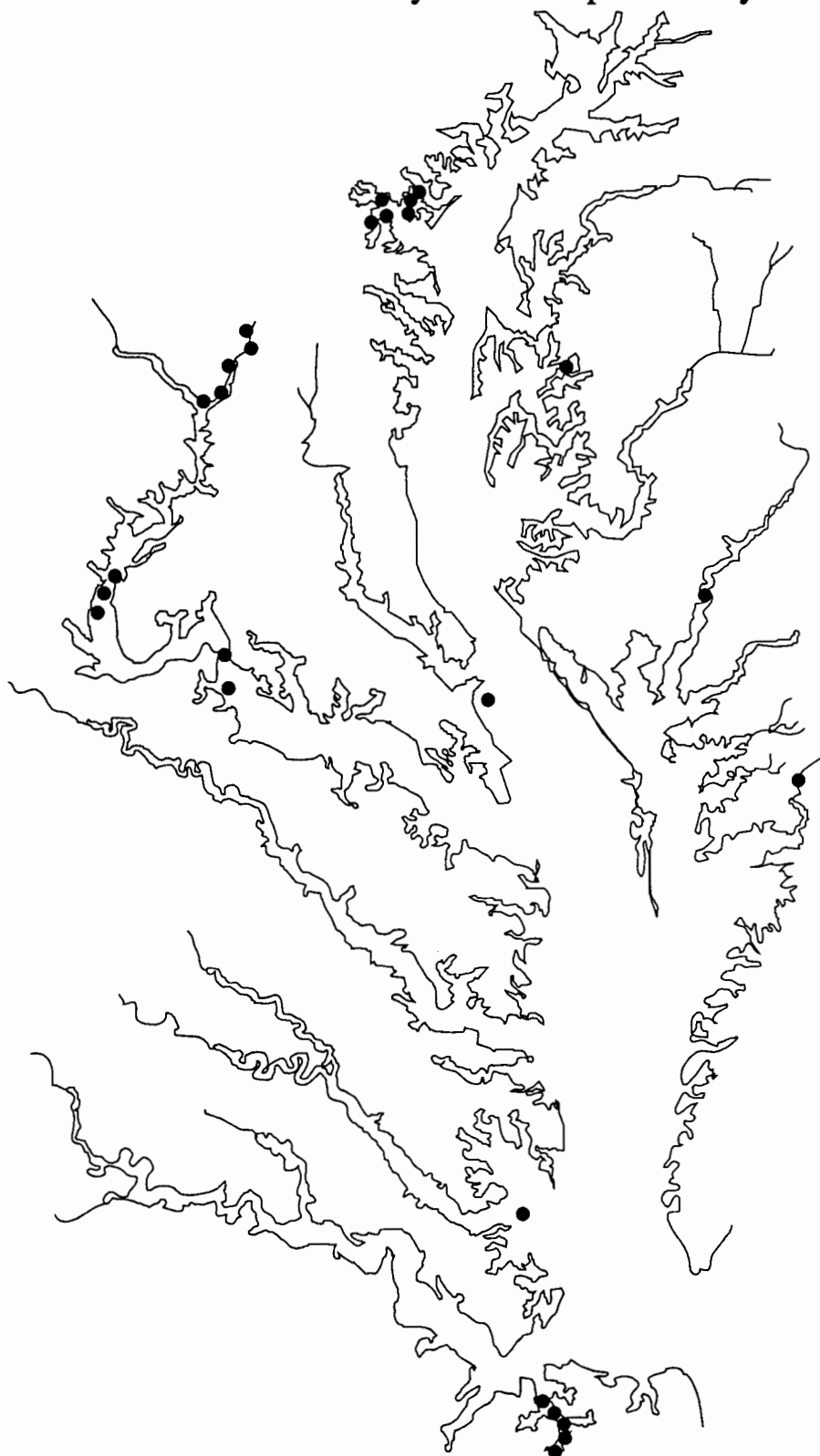
REGION	YEARS	OBSERVED EFFECTS	SOURCES
Elizabeth River	1989	Fish exposed to 100 percent Elizabeth River sediment (contaminated with PAHs) were dead in two hours. $LT_{50}$ (lethal time) was determined to be 57 minutes. A series of 24 hour $LC_{50}$ values were determined for various percentages of contaminated Elizabeth River (ER) sediments mixed with uncontaminated "clear" sediments: 56% ER sediment, 24 hours; 51% ER sediment, 7 days; 16% ER sediment, 12 days; 2.9% ER sediment, 21 days; and 2.5% ER sediment, 28 days.	Roberts et al. 1989
Elizabeth River	1989	Intestines and liver microsomes of spot collected from the Elizabeth River sites contaminated with PAHs were found to have elevated levels of the enzymes cytochrome P-450 and ethoxyresorfin o-deethylase (EROD) when compared to reference sites. The fate and effects of PAHs in aquatic organisms are controlled by various xenobiotic metabolizing enzymes, including cytochrome P-450.	Van Veld et al. 1990
Elizabeth River	1990	Mummichog collected from an area of the Elizabeth River contaminated with PAHs were found to have a high incidence of idiopathic hepatic lesions.	Gassner et al. 1990
Elizabeth River	1990	Significant reductions in survival reported for the copepod <i>Eurytemora affinis</i> and grass shrimp upon exposure to ambient water. All test of ambient sediment toxicity exhibited 100 percent mortality within the first 10 days of exposure for all test species - grass shrimp ( <i>Palaemonetes pugio</i> ) polychaete worm ( <i>Streblospio benedicti</i> ) and amphipod ( <i>Lepidactylus dytiscus</i> ).	Hall et al. 1991
Wye River	1990	Significant reductions in both survival and growth and survival reported for amphipods ( <i>Lepidactylus dytiscus</i> ) and polychaete worms ( <i>Streblospio benedicti</i> ), respectively, upon exposure to ambient sediments.	Hall et al. 1991a
Wye River	1991	Significant reductions in survival for the copepod <i>Eurytemora affinis</i> reported upon exposure to ambient waters. Significant reductions in survival of polychaete worms ( <i>Streblospio benedicti</i> ) upon exposure to ambient sediments.	Hall et al. 1992c
Wye River	1992-1993	Significant reductions in survival of the copepod <i>Eurytemora affinis</i> reported upon exposure to ambient waters. Exposure to ambient sediments produced reduced survival in the amphipod <i>Lepidactylus dytiscus</i> and reduced growth in the amphipod <i>Leptocheirus plumulosus</i> .	Hall et al. 1994b



**Table 43 (con't.)** Summary of Chesapeake Bay ambient effects findings.

REGION	YEARS	OBSERVED EFFECTS	SOURCES
Nanticoke River	1984	Striped bass larvae (one day old) placed in environmental test chambers were exposed to the Nanticoke River for 96 hours in <i>in-situ</i> experiments to determine whether contaminants in the river inhibited early life stage survival; three locations, representing 8.8 kilometers of spawning habitat were tested. Water quality measurements were made at each site. After 96 hours of exposure to the Nanticoke River, striped bass larvae survival was less than 10%; control was >75%. Dissolved aluminum levels were elevated (mean concentration was 0.12 mg/L in filtered samples with a concentration range of 0.039-0.181 mg/l). At low pH (6.0-6.8), elevated aluminum concentration and salinity were factors influencing mortality.	Hall 1984, Hall et al. 1985
Nanticoke River	1992	A pattern of reduced survival upon exposure to ambient sediments reported in the amphipods ( <i>Lepidactylus dytiscus</i> and <i>Leptocheirus plumulosus</i> ) and polychaete worms ( <i>Streblospio benedicti</i> ) tested.	Hall et al. 1994b
Chesapeake Bay Tributaries	1982-84	White perch adults were collected from fifteen Chesapeake Bay estuarine tributaries to determine incidence of liver neoplasia. Neoplasms were found in the livers, exhibiting a variety of inflammatory, hyperplastic and putative preneoplastic lesions of bile ductular and hepatocellular origin. Chronic pericholangitis was the most prevalent inflammatory lesion noted.	May et al. 1987

### Sediment Toxicity in Chesapeake Bay



**Figure 23.** Sites in Chesapeake Bay where ambient sediment toxicity has been observed (●) to be statistically different from control sediment toxicity tests. Sources: Chesapeake Bay Program 1993d; Hall et al. 1991a, 1992c; Velinsky et al. 1992; Weisberg et al. 1992.

These findings are based on studies often conducted at individual sites or groups of sites within much larger tidal tributaries and regions of the mainstem Bay. The adverse effects attributed to the presence of chemical contaminants may also be the result of other adverse environmental conditions present during the study—low pH, rapid temperature shifts, low dissolved oxygen, or elevated sediment ammonia concentrations.

### ***WATER COLUMN EFFECTS***

Ambient water column conditions toxic to vertebrates (e.g., finfish larvae) and invertebrates (e.g., clams, copepods, grass shrimp, and daphnids) have been documented in the Elizabeth, Patapsco, Wye, and Potomac rivers [110, 113, 114, 139, 284]. During in situ ambient toxicity tests, striped bass larvae and juveniles exposed to Potomac river water and larvae exposed to Choptank and Nanticoke river water suffered extremely high mortality. In some rivers such as the Nanticoke and Choptank, this mortality has been attributed to a combination of low pH and high metal concentrations [77, 78, 102, 103, 123, 124, 200, 201, 242] (Table 43). In the Potomac River—a more buffered system—the mortality of young larvae is more likely attributable to metals and sudden decreases in temperature [126, 127, 200]. Rivers whose watersheds are predominantly within the Coastal Plain tend to be especially susceptible to acid conditions.

### ***SEDIMENT TOXICITY EFFECTS***

Data on sediment toxicity in Chesapeake Bay are very limited with most of the recent data generated by the Chesapeake Bay Program's Ambient Toxicity Assessment Program, Maryland Department of the Environment field studies, and the EPA Environmental Monitoring and Assessment Program. Other limited sediment

toxicity data are available for specific studies or sites.

Sediment toxicity has been well documented in various locations in the Elizabeth [2, 3, 23, 114, 160, 192, 254], Patapsco [113, 114, 192, 242, 290], and Anacostia [232, 233, 237, 307] rivers (Table 43; Figure 23). Sediment toxicity also has been documented in the Potomac [113, 114, 192], Pocomoke [324], Nanticoke [110], and Wye [110, 113, 114] rivers. Sediment toxicity in these systems, which were generally considered unimpacted by chemical contaminants, raises concerns about other regions of the Bay generally not considered to be areas with toxics problems.

Since much of the sediment toxicity data reported for the Bay is based on mortality as an endpoint, very little is known about the potential chronic effects (on growth and reproduction) of sediment contamination in Chesapeake Bay. Short-term laboratory toxicity testing provides limited information on the long-term effects of exposure to lower levels of sediment contamination.

### ***HISTOPATHOLOGICAL/ SUBORGANISMAL EFFECTS***

Numerous studies have shown evidence of adverse effects in organisms inhabiting the Elizabeth, Patapsco, and Anacostia rivers (Table 43). Effects include compromised immune systems [318, 319, 320], induced enzyme systems related to chemical exposure [114, 305], histological abnormalities such as liver tumors, gill pathology, cataracts, and lesions on the kidney and the skin, reduced respiratory and osmoregulatory ability, and mortality [2, 3, 23, 46, 117, 118, 123, 124, 126, 127, 133, 134, 136, 160, 237, 254, 288, 314].

#### ***Box 6. Sources of further information on Chesapeake Bay ambient toxicity effects***

*Chesapeake Bay Ambient Toxicity Assessment Program Reports* [110, 113, 114]

*Chesapeake Bay Ambient Toxicity Assessments Workshop* [170]

*Chesapeake Bay Striped Bass Contaminant Studies* [77, 78, 102, 103, 105, 106, 107, 111, 112, 115, 117, 118, 123, 124, 126, 127]

*Low-Level Effects of Toxic Chemicals on Chesapeake Bay Organisms* [338]

Still other studies have documented similar effects in areas not necessarily having elevated concentrations of chemical contaminants and in some areas previously thought uncontaminated (Table 43). For example, one study has shown that water from the Rappahannock River had genotoxic effects on the American oyster [208]. Menhaden with severe skin ulcers have been sampled in the Rappahannock, as well as the York, and James rivers and the mainstem Bay [135]. Other areas where liver pathology indicates adverse effects in fish include the Choptank, Potomac, Susquehanna, Back, and Severn rivers and the Chesapeake and Delaware Canal [35, 117, 118, 123, 124, 126, 127, 198]. Similarly, adverse effects on fish gills have been documented in striped bass yearlings from the Chesapeake and Delaware Canal and the Nansemond, Choptank, Potomac, Susquehanna, Elk, and Sassafras rivers [126, 127, 133, 134, 138]. Kidney lesions developed in striped bass exposed to Potomac River water [126, 127].

## ***FINDINGS AND CONCLUSIONS***

Adverse impacts on aquatic organisms have been observed in a variety of Bay habitats. Observation of these adverse ambient effects in Bay habitats such as the Nansemond, Elk, Sassafras, and Wye rivers, generally considered to be unimpacted by chemical contaminants, raises concerns about other regions of the Bay generally not regarded as toxic problem areas. The presence of potentially toxic chemicals in these areas suggests that the combined effects of multiple chemical contaminants may be a factor in causing the observed effects—death, reduced growth and reproduction, tumors. Outside of the highly chemically contaminated areas of the Bay, however, it is not known if these adverse effects are caused by chemical contaminants or by other environmental conditions not related to chemical contamination.

## **Finfish and Shellfish Tissue Contamination**

A Chesapeake Bay Contaminated Finfish and Shellfish Critical Issue Forum sponsored by the Toxics Subcommittee was held in March 1993 as part the reevaluation of the basinwide strategy [46]. The critical issue forum was structured to reach a technical consensus on: 1) the relative magnitude (concentration) and extent (geographical distribution) of finfish and shellfish tissue contamination within Chesapeake Bay and within the Chesapeake Bay basin; 2) determination of impacts (i.e., bioaccumulation, toxicity) on the Chesapeake Bay system on either a basinwide, baywide, regional, or local scale; and 3) comparison of the magnitude and extent of Bay finfish and shellfish tissue contamination with other systems. The findings from the critical issue forum are summarized here.

The majority of available fish tissue data are based on analysis of the edible portion of the fish; these data were generally collected to ensure that tissue concentrations are safe for human consumption. Whole fish data and NOAA National Status and Trends Program fish liver concentration data, however, also give a general indication of concentrations in other fish tissues. The relationship between whole fish tissue concentrations or liver concentrations and the health of the fish is not known. All three types of tissue data—edible portion, whole fish, and liver—are valuable in determining trends of chemical concentrations if the data are collected routinely over a sufficient time period.

### ***FINFISH TISSUE CONTAMINATION***

#### **National Oceanic and Atmospheric Administration**

From 1984 to 1987, croaker and spot liver concentrations of chlordane, PCBs, dieldrin, and

total DDT concentrations in the Chesapeake Bay were elevated above the national average and the national median for these species at NOAA National Status and Trends Program stations [46]. During the same period, trace metal results showed that chromium, arsenic, lead, and mercury were generally high in croaker livers and that chromium, silver, lead, nickel, copper, and tin were occasionally high in some of the spot livers compared to the national average.

### **New York**

There are no finfish consumption advisories in the New York portion of the Chesapeake Bay basin (Table 44; Figure 23).

### **Pennsylvania**

Available data indicate elevated contaminant concentrations in finfish tissue are limited to three stream and river reaches within the Susquehanna River basin. Finfish consumption bans and advisories are in effect due to PCBs, mirex, or dioxin (Table 44; Figure 24). Smallmouth bass fillet data presented for the Susquehanna River mainstem from 1984 to 1988 showed data values were <0.20 ppm for PCBs, <0.05 ppm for chlordane, and <0.05 ppm for DDT. Data for the Potomac River basin in Pennsylvania (4 species at 4 stations) for 1989 and 1991 showed all collected fish samples had tissue concentrations <0.25 ppm for PCBs, <0.005 ppm - <0.02 ppm for chlordane, and <0.01 - 0.22 ppm for DDT [46]. All these measured concentrations fall well below levels established for protection of human health.

### **Maryland**

Several finfish consumption advisories are presently in effect in Maryland within the Chesapeake Bay basin (Table 44; Figure 24). These advisories focus on the consumption of eels, carp, catfish, and black crappie due to chlordane contamination.

During the 1990 sampling and analysis of finfish tissue at Maryland's Chesapeake Bay tidal stations, measurable concentrations of mercury, PCBs, chlordane, cadmium, and nickel were observed [46]. Dieldrin was detected in only three samples (whole body).

Mercury concentrations were low with little variation in samples from all sub-basins sampled for finfish tissue in 1990: the Potomac, Patuxent, West Chesapeake, Patapsco, Gunpowder, Bush, Sassafras, Chester, Choptank, Nanticoke, and Pocomoke rivers (Figure 25). Among the areas sampled, the Patapsco River station had the highest concentrations of PCBs and chlordane. Although lower than the Patapsco concentrations, PCBs were present in white perch from urban watersheds (Bush, Gunpowder, West Chesapeake, and Potomac) at concentrations greater than the more rural watersheds (Patuxent, Nanticoke, Choptank, and Chester). One exception to this trend was exhibited by the channel catfish data which included elevated concentrations at the Sassafras River station. Chlordane concentrations in white perch from the Choptank, Chester, Gunpowder, Patuxent, and Potomac rivers were less than one third of those in the Patapsco River and were non-detectable in white perch collected from the Nanticoke, Bush, and West Chesapeake sub-basins (Figure 25).

Among the stations sampled, cadmium concentrations were highest in the channel catfish collected from the Sassafras River station. Cadmium was not detected in finfish tissue samples from the Patapsco and Pocomoke rivers. Concentrations in finfish tissue samples from the other sub-basins—the Potomac, Patuxent, West Chesapeake, Gunpowder, Bush, Chester, Choptank, and Nanticoke—were detectable, but fell below those at the Sassafras River station. Nickel concentrations varied among the areas sampled, with below detection limit concentrations observed in the Patapsco, West Chesapeake, and Pocomoke sub-basins and the highest concentrations at the Chester, Bush, and Patuxent river

**Table 44.** Chesapeake Bay basin finfish and shellfish consumption bans and advisories.

**New York**

No consumption bans or advisories in the Chesapeake Bay basin.

**Pennsylvania**

1. Susquehanna River (mouth of Lackawanna River at Pittstown to the Village of Humlock Creek) — PCBs advisory on consumption of suckers and carp.
2. Spring Creek — ban on fishing because of mirex contamination.
3. Codorous Creek and Little Codorous Creek — dioxin advisory on consumption of green sunfish.

**Maryland**

4. Back River — chlordane advisory on consumption of eels, carp, and catfish.
5. Baltimore Harbor — chlordane advisory on consumption of eels, carp, and catfish.
6. Lake Roland — chlordane advisory on consumption of black crappie and carp.

**District of Columbia**

7. Anacostia River — chlordane and PCBs advisory on consumption of catfish, carp, and eels.
8. Potomac River — chlordane and PCBs advisory on consumption of catfish, carp, and eels.

**Delaware**

No consumption bans or advisories in the Chesapeake Bay basin.

**Virginia**

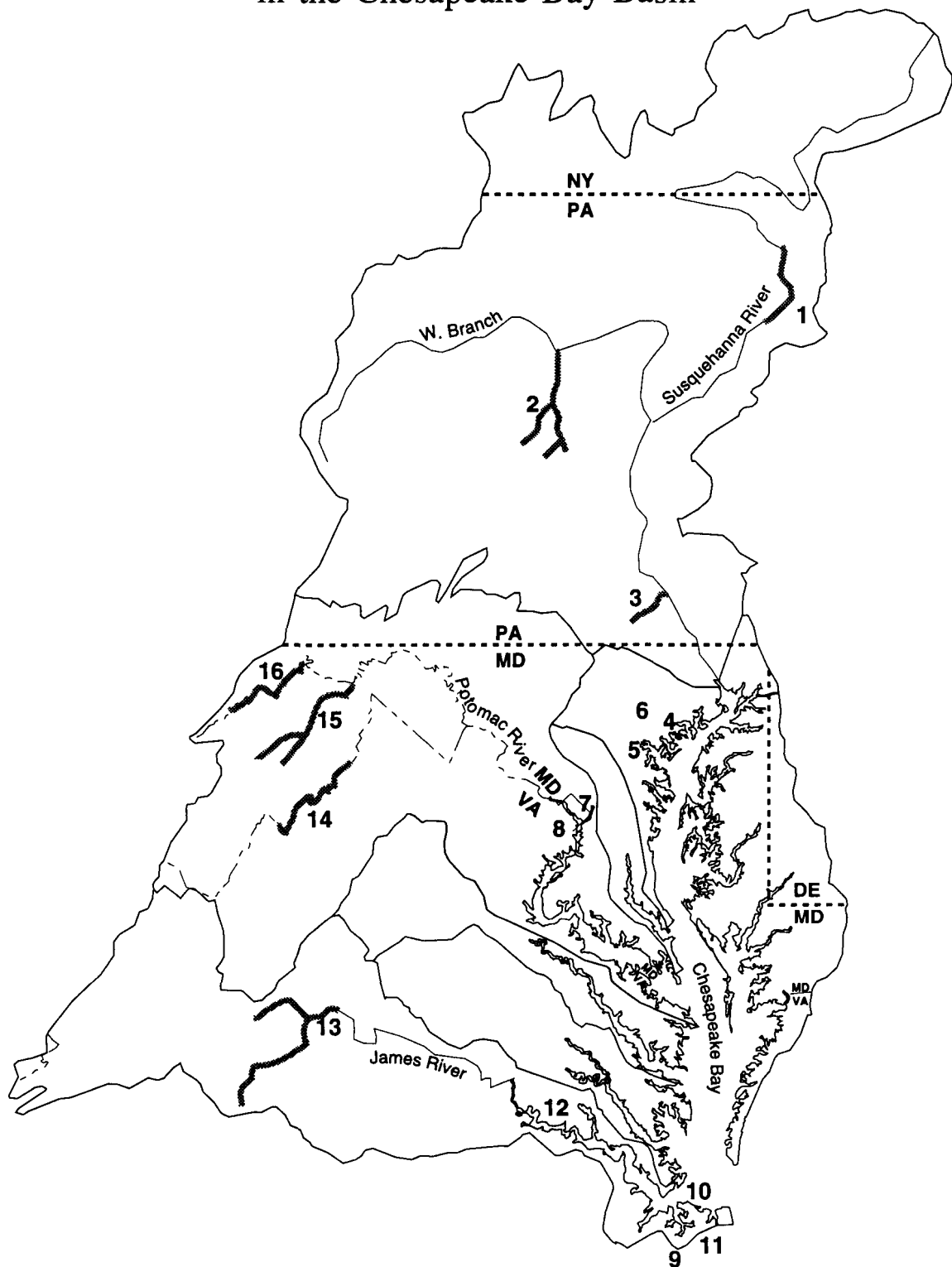
9. Elizabeth River — shellfish taking prohibited.
10. Layfayette River — shellfish taking prohibited.
11. Little Creek — shellfish consumption restrictions.
12. James River (tidal river and its tributaries) — kepone advisory.
13. Jackson River and upper James River — dioxin advisory on consumption of fish.
14. South Fork Shenandoah River and South River — mercury advisory on consumption of fish.
15. South Fork Shenandoah River, North Fork Shenandoah River, and Shenandoah River — PCBs advisory on consumption of fish.

**West Virginia**

16. Shenandoah River — PCB advisory on consumption of carp, channel catfish, and suckers.

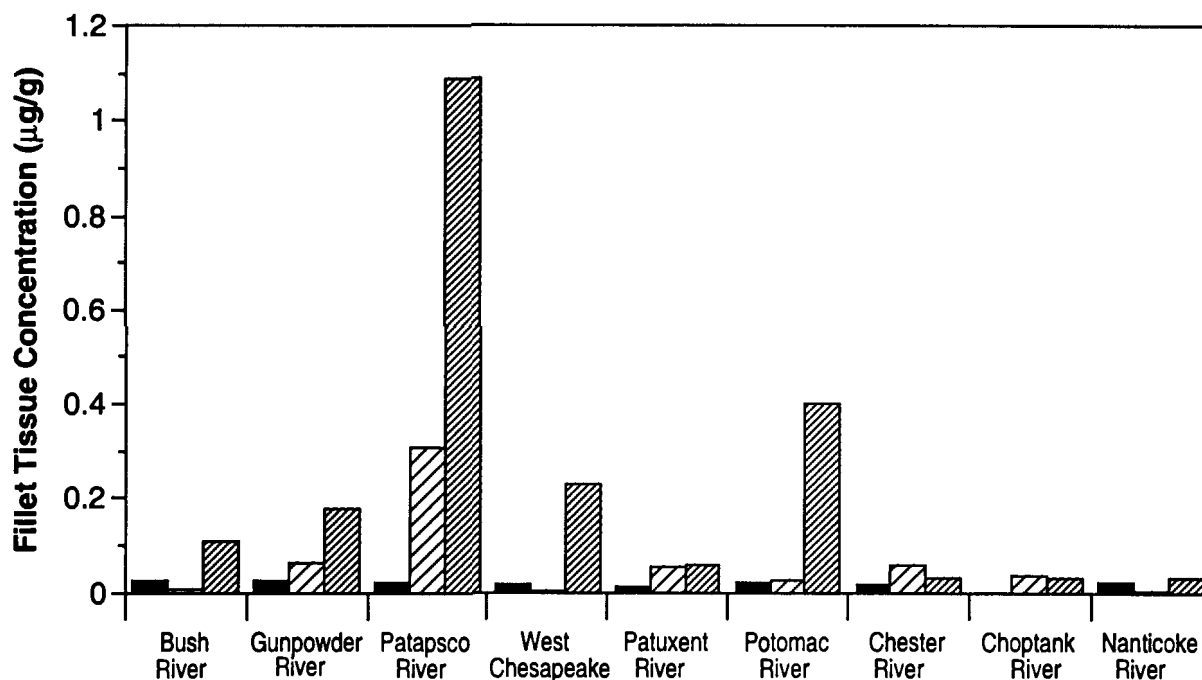
Sources: Chesapeake Bay Program 1993b; U.S. EPA 1994c.

## Finfish and Shellfish Consumption Bans and Restrictions in the Chesapeake Bay Basin



**Figure 24.** General location of the finfish and shellfish consumption bans and advisories within the Chesapeake Bay basin. The numbers refer to specific streams, lakes, and rivers listed in Table 44. Source: Chesapeake Bay Program 1993b.

### Concentrations of Mercury, Chlordane, and PCBs in White Perch – 1990



**Figure 25.** Concentrations of mercury (■), chlordane (▨), and PCBs (▩) in white perch fillet tissue collected in the Maryland portion of the Chesapeake Bay in 1990. West Chesapeake includes the Magothy, Severn, South, West, Rhode rivers and mainstem Bay from Herring Bay to Drum Point. Source: Maryland Department of the Environment, unpublished data (d).

stations. Concentration of aldrin, alpha-BHC, chromium, dacthal, DDD, DDE, DDT, endosulfan, endrin, gamma-BHC, heptachlor, heptachlor epoxide, hexachlorobenzene, methoxychlor, and mirex were not detected in any of the 1990 samples.

Tissue contaminant concentrations for three size classes of striped bass (<18 inches, 18-24 inches, and 24-33 inches) collected from the Potomac River in 1986, 1988, and 1991 showed declines over time [46]. Tissue concentrations of mercury showed a statistically significant decline in the largest size class (24-33 inches) from 1986 to 1991. Arsenic, cadmium, and lead also exhibited decreasing concentrations for that time period in some of the three size classes. Tissue concentrations of chlordane have decreased in all three size classes with the most notable decline in the largest size class. A decrease in PCB concentrations occurred 1988 to 1991 (the only two years

for which PCB data were available). Concentrations of zinc and copper, for which the sources may be natural as well as anthropogenic, appear to have increased slightly from 1986 to 1991. All of these measured concentrations are not of concern as they fall well below levels established for the protection of human health.

#### District of Columbia

Based on findings from the District of Columbia's Finfish Tissue Contaminant Monitoring Program and other surveys within the district's waters, the major finfish tissue contaminants are PCBs and chlordane [46]. Concentrations of PCBs are generally near U.S. Food and Drug Administration (FDA) action levels if whole fish are analyzed; the fillets contain PCB concentrations that are usually below FDA action levels. Finfish consumption advisories are presently in effect for the District of Columbia's portions of



the Potomac and Anacostia rivers (Table 44; Figure 24).

Chlordane concentrations were high in sunfish in the upper and lower Anacostia River in 1986. Chlordane levels appeared to be lower in 1988 but comparisons are difficult because of the inconsistent laboratory methods used for finfish tissue analyses. In catfish, concentrations were high in 1986 for all three sites; the upper and lower Anacostia River concentrations approached 2.0 ppm. Data for the lower (1987) and upper (1988) Anacostia River showed elevated concentrations of chlordane in catfish.

For PCBs in sunfish, 1986 whole fish concentrations were all above the FDA action level of 2.0 ppm. The lower Anacostia River had PCB tissue concentrations approaching 6 ppm. High concentrations of PCBs also occurred in 1987 and 1988 although the upper Anacostia River tissue concentrations were lower.

Dieldrin concentrations for channel catfish tissue were above 0.05 ppm in the lower Anacostia River but below the FDA action level of 0.3 ppm. Tissue concentrations of DDT were also high at sampling sites in the Potomac and lower Anacostia rivers, reaching 0.5 ppm in channel catfish.

### Delaware

In whole body samples of Nanticoke River and Broad Creek finfish, traces of cadmium, chromium, copper, DDT metabolites, dieldrin, mercury, and zinc have been detected but at levels well below those established for the protection of human health [46]. Concentrations of aldrin, alpha-BHC, aluminum, arsenic, beta-BHC, chlordane, DDD, DDE, DDT, delta-BHC, diazinon, dieldrin, endosulfan I and II, endosulfan sulfate, endrin, endrin aldehyde, gamma-BHC, heptachlor, heptachlor epoxide, hexachlorobenzene, lead, methoxychlor, methyl parathion, nickel, PCBs (aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260), selenium, silver, and toxaphene were not detected. In the edible portion of the fish, DDE

was detected in all three samples from Broad Creek, whereas concentrations of DDD, DDT, dieldrin, and PCBs were not detected. There are no finfish consumption advisories in the Delaware portion of the Chesapeake Bay basin (Table 44; Figure 24)

### Virginia

Several fish consumption bans and advisories are currently in effect in Virginia within the Bay basin (Table 44; Figure 24). Beyond these areas, recent sampling by the Virginia Department of Environmental Quality has indicated elevated concentrations of arsenic (Rappahannock, York, and James rivers), copper (Potomac River), and lead (York and James rivers) in finfish tissue [46].

### West Virginia

Within West Virginia's portion of the Bay basin, there is a finfish consumption advisory for PCB contamination in the Shenandoah River. The advisory recommends restricting the consumption of channel catfish, suckers, and carp (Table 44; Figure 24).

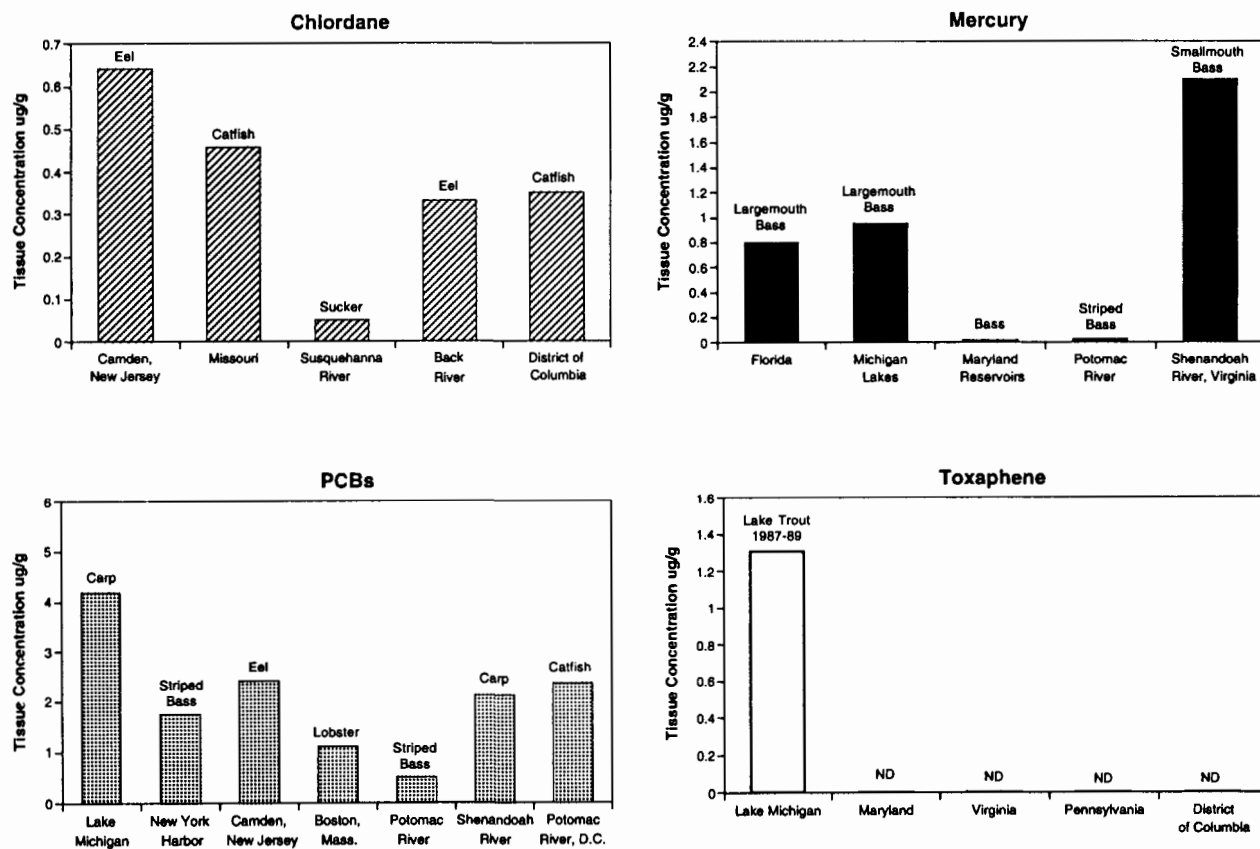
### Comparison of Bay Finfish Tissue Concentrations with Nationwide Data

Figure 26 compares concentrations of chlordane, mercury, PCBs, and toxaphene in finfish tissue from problematic areas of the Chesapeake Bay basin with concentrations in finfish tissue from areas across the country considered contaminated. The comparison of Chesapeake Bay finfish tissue concentrations of chlordane indicates that the Back and Anacostia rivers (where consumption advisories are in place) have concentrations substantially elevated over Susquehanna River concentrations (Figure 26). Chlordane tissue concentrations, however, are higher in known contaminant problem areas elsewhere in the country—Camden, New Jersey where eels had chlordane tissue concentrations in excess of 0.6 ppm and Missouri where chlordane tissue concentrations in catfish exceeded 0.4 ppm.

With the exception of a reach of the Shenandoah River where an advisory is in place, mercury tissue concentrations throughout the Chesapeake Bay basin (generally <0.1 ppm) are well below those at national areas with known contamination problems such as lakes in Florida where largemouth bass had mercury tissue concentrations exceeding 0.8 ppm and Michigan lakes where mercury tissue concentrations in largemouth bass were near 1 ppm (Figure 26).

For PCBs in finfish fillets, comparisons were made among carp from Lake Michigan, striped bass from New York Harbor, eel from Camden, New Jersey, lobster from Boston, striped bass from the lower Potomac River, sunfish from the Shenandoah River, and catfish from the District of Columbia portion of the Potomac River (Figure 26). Lake Michigan carp had the highest concentrations (4-5 ppm) followed by eel from Camden, New Jersey (2 ppm). Striped bass from

### Comparisons of Chesapeake Bay Fish Tissue Concentrations with Sites Across the Country



**Figure 26.** Comparisons of Chesapeake Bay finfish fillet tissue concentrations with other areas of the nation with known, elevated fillet tissue concentrations for chlordane, mercury, PCBs, and toxaphene. ND = none detected. Sources: Chesapeake Bay Program 1993b; Collier Personal Communication; Czarneski 1989; Frey Personal Communication; Gregory Personal Communication; Hand and Friedemann 1990; Hauge et al. 1990; Michigan Department of Natural Resources 1990; Murphy Personal Communication; Schwartz et al. 1991; Sloan et al. 1991.

the lower Potomac River had the lowest PCB tissue concentrations.

As there are no specific areas with elevated finfish tissue concentrations of toxaphene in the Chesapeake Bay basin, toxaphene concentrations in lake trout fillets from Lake Michigan (1987 to 1988) were compared to the most recent tissue data for Maryland, Pennsylvania, and the District of Columbia finfish. All 1990 data for Maryland were below detection limits, as were the data for Pennsylvania, Virginia, and the District of Columbia (Figure 26).

### ***SHELLFISH TISSUE CONTAMINATION***

#### **National Oceanic and Atmospheric Administration**

Compared to the national data (polycyclic aromatic hydrocarbons concentrations in Boston Harbor and Puget Sound and DDT concentrations in the Gulf of Mexico and Southern California) concentrations in Chesapeake Bay oyster tissue are relatively low [46]. The 1990 NOAA National Status and Trends Program oyster tissue data for Chesapeake Bay do, however, show some significant patterns when compared to national average and median concentrations.

Tissue concentrations of polycyclic aromatic hydrocarbons were highest in the upper mainstem Bay at the mouth of the Patapsco River and in the Elizabeth River. Total PCBs and total DDT concentrations were highest at the northern (upper mainstem Bay) and southern (James River) Bay stations. Chlordane tissue concentrations were highest at the northern Bay stations. Total butyltin tissue concentrations were highest at the northern Bay and James River stations. Lead tissue concentrations were low compared with the national median concentration. Nickel tissue concentrations were high at all Chesapeake Bay stations, especially the northern Bay stations, compared with the national median concentration. Cadmium tissue concentrations were also high at stations near the Patapsco River and

within Baltimore Harbor, compared with the national median concentration. Mercury tissue concentrations were lower than the national median concentration at all the Chesapeake Bay stations. Arsenic tissue concentrations clustered around the national median concentration.

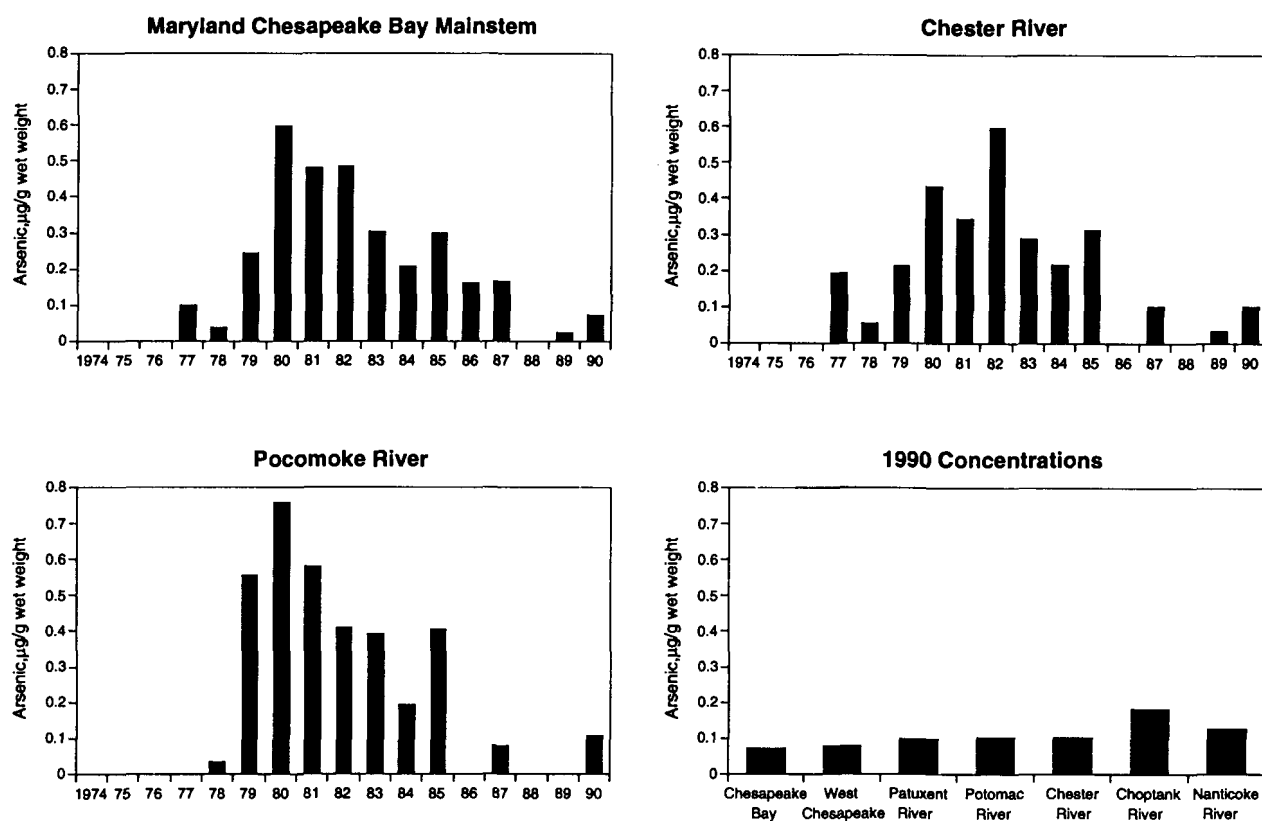
Some trends become apparent in comparing the 1989 NOAA National Status and Trends shellfish data with the EPA Mussel Watch Program data of the 1970s. Both programs sampled at three of the same common sites. According to Lauenstein et al. [172], there was statistical decrease in zinc concentrations at all stations except one on the lower Virginia Eastern Shore where an increase could have been associated with marina construction.

Using only NOAA National Status and Trends Mussel Watch Project data, other trends are visible between 1986 and 1991. Concentrations of chlordane, DDT, dieldrin, and PCBs have declined consistently over time. The region adjacent to the Patapsco River mouth showed an increase in polycyclic aromatic hydrocarbons from 1988 to 1989, perhaps tied to a local spill. There have been both decreases and increases in tissue concentrations since 1986 for most metals. Silver tissue concentrations decreased until 1988, at which time a statistically significant increase occurred. Chromium tissue concentrations followed the same pattern. A pattern of a decrease followed by an increasing trend occurred at the northern Bay sites for copper tissue concentrations. Since the same temporal pattern was documented at NOAA stations along the East Coast north to Long Island Sound, it could be correlated to a climatic or natural change along the Atlantic coast.

#### **Maryland**

Over nearly two decades of data, declines have been recorded in oyster tissue concentrations of arsenic, cadmium, mercury, zinc, and chlordane in the Maryland portion of the Chesapeake Bay (Figures 27-31). Significant declines

## Maryland Oyster Tissue Arsenic Concentration Trends



**Figure 27.** Concentrations of arsenic in oyster tissue in the Maryland portion of Chesapeake Bay from 1974-1990. West Chesapeake includes the Magothy, Severn, South, West, and Rhode rivers and the mainstem Bay from Herring Bay to Drum Point. Sources: Eisenberg and Topping 1981; Garreis and Pittman 1981a, 1981b, 1982; Garreis and Murphy 1986a, 1986b; Maryland Department of the Environment unpublished data (d); Murphy 1990.

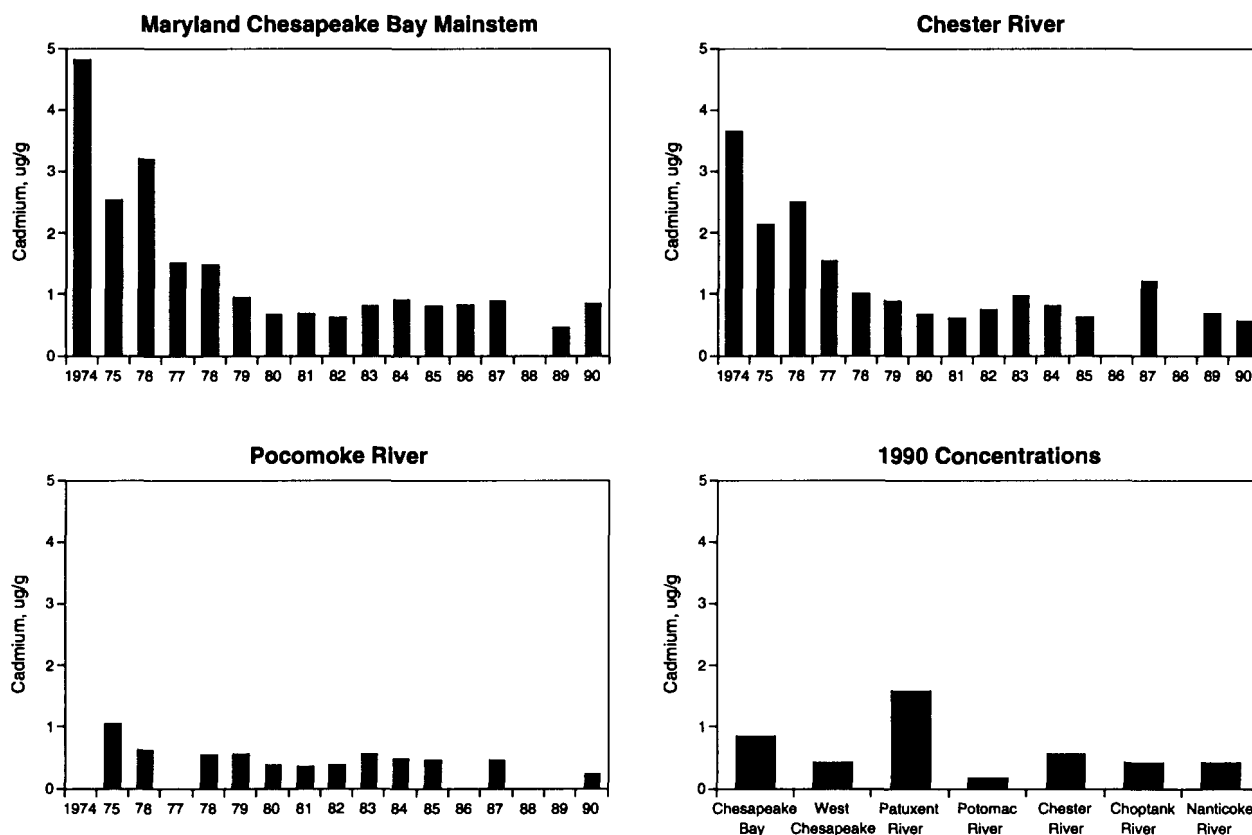
in the metal concentrations in the 1970s are followed by relatively consistent concentrations throughout the 1980s. Chlordane concentrations declined throughout the data record and concentrations were no longer detected by 1990.

During Maryland's 1990 monitoring of oyster tissue concentrations, mercury concentrations were less than 0.01 percent of the FDA action level at all locations, with the Potomac River concentrations slightly higher than those for the other sub-basins (Figure 29). With the exception of oysters collected from the West Chesapeake and Choptank river sub-basins, PCB concentrations were below the detection limit in oysters

from the 1990 collection areas (Figure 32). Nickel and manganese are recent additions to Maryland's program, therefore, no historical data were available. In the 1990 data, oysters appear to accumulate higher tissue concentrations of manganese than nickel. Little variation was observed among the collection areas for either metal.

The observed 1990 oyster tissue concentrations were not of concern because they fall well below levels established for protection of human health. Concentrations of aldrin, alpha-BHC, chlordane, chromium, dacthal, DDD, DDE, DDT, dieldrin, dacthal, endosulfan, endrin, gamma-BHC, heptachlor, heptachlor epoxide,

## Maryland Oyster Tissue Cadmium Concentration Trends



**Figure 28.** Concentrations of cadmium in oyster tissue in the Maryland portion of Chesapeake Bay from 1974-1990. West Chesapeake includes the Magothy, Severn, South, West, and Rhode rivers and the mainstem Bay from Herring Bay to Drum Point. Sources: Eisenberg and Topping 1981; Garreis and Pittman 1981a, 1981b, 1982; Garreis and Murphy 1986a, 1986b; Maryland Department of the Environment, unpublished data (d); Murphy 1990.

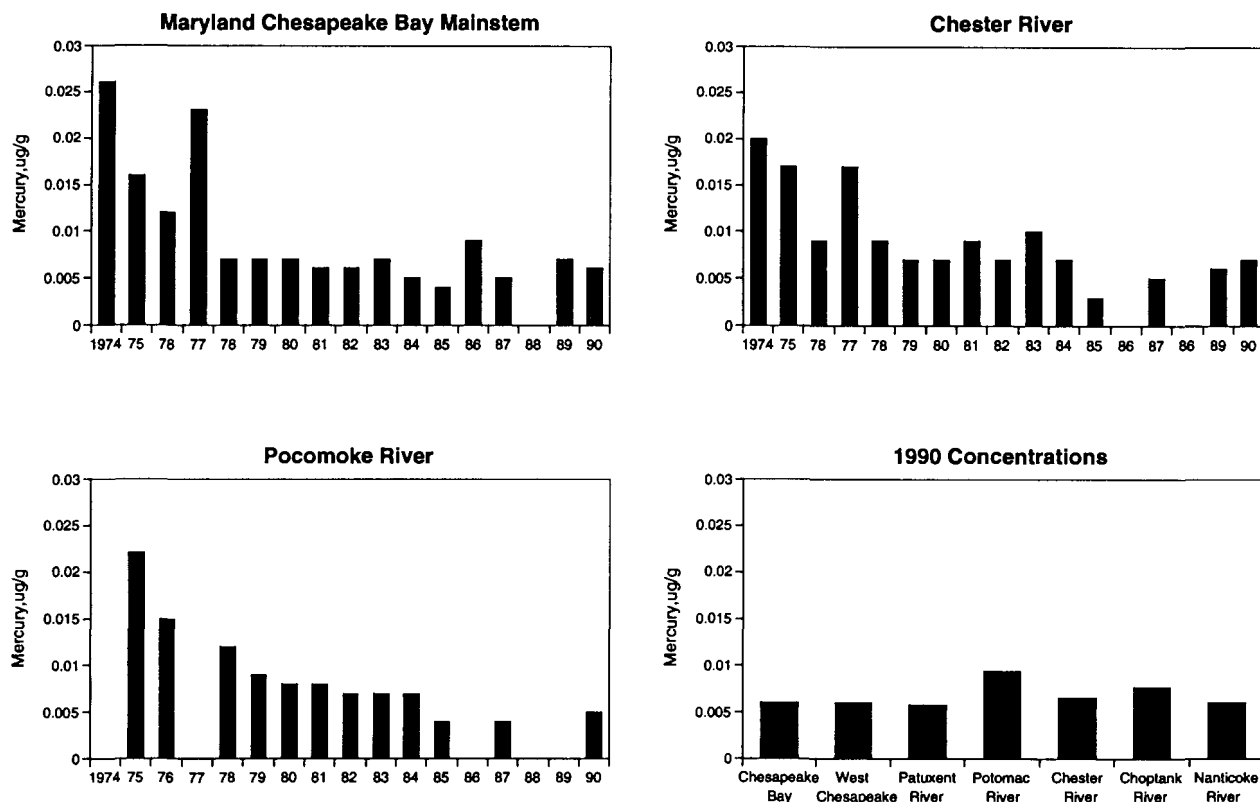
hexachlorobenzene, methoxychlor, mirex, and toxaphene were not detected in oyster tissue during the 1990 survey.

During Maryland's 1990 intensive survey of 25 chemicals in blue crabs, the only organic chemicals detected were chlordane and PCBs. Laboratory procedures for chlordane analysis changed between the 1983 and 1990 blue crab surveys, however, these data indicate a decline in blue crab chlordane concentrations from the Patapsco River (i.e., Baltimore Harbor) and a small rise for chlordane in blue crab concentrations from the Magothy River. The other areas surveyed both years (Choptank River, Eastern

Bay, Gunpowder River, and Herring Bay) showed little difference in blue crab tissue concentrations between the two collections. Data for PCB concentrations in blue crab tissue are only available for the 1990 collection. With the exception of the Patapsco River blue crab tissue samples, PCB concentrations were at or below the detection limit at all collection sites.

Mercury concentrations in blue crab tissue showed little change between the 1983 and 1990 collections; all concentrations were approximately 0.01 percent of the FDA action level. With the exception of the Gunpowder and Patapsco rivers, arsenic tissue concentrations declined between

## Maryland Oyster Tissue Mercury Concentration Trends



**Figure 29.** Concentrations of mercury in oyster tissue in the Maryland portion of Chesapeake Bay from 1974-1990. West Chesapeake includes the Magothy, Severn, South, West, and Rhode rivers and the mainstem Bay from Herring Bay to Drum Point. Sources: Eisenberg and Topping 1981; Garreis and Pittman 1981a, 1981b, 1982; Garreis and Murphy 1986a, 1986b; Maryland Department of the Environment, unpublished data (d); Murphy 1990.

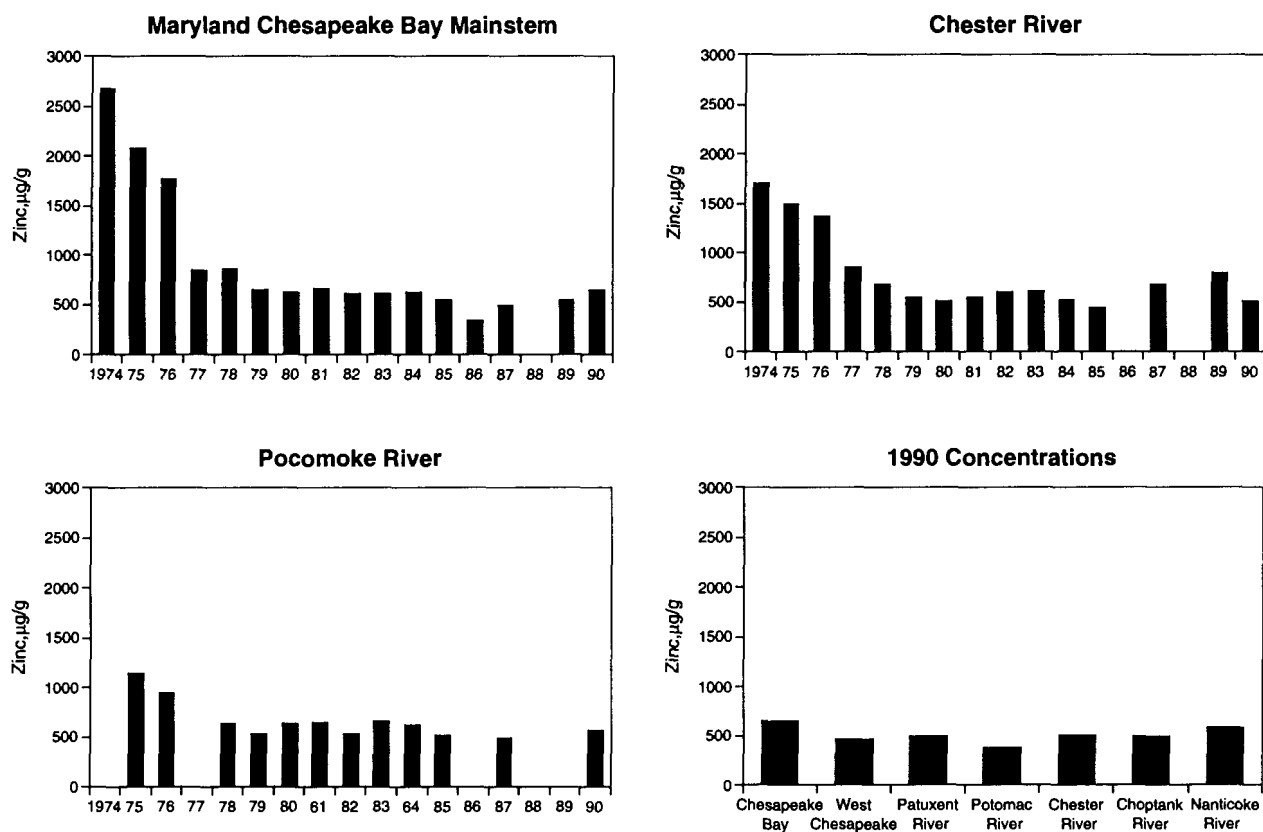
1983 and 1990 at all areas sampled in both surveys (Choptank River, Eastern Bay, Herring Bay, and Magothy River). Blue crab tissue concentrations from the Gunpowder and Patapsco rivers stayed the same or increased slightly between the 1983 and 1990 collections. Cadmium and lead tissue concentrations in blue crabs declined from 1983 to 1990 at all areas sampled during both collections. In the case of lead, the 1990 blue crab tissue concentrations were below detection limit for all samples collected from the Choptank River, Eastern Bay, Gunpowder River, and Herring Bay.

Zinc and copper exhibited increasing concentrations in blue crab tissue from all areas surveyed

in 1983 and 1990, with the exception of the Choptank River site where a slight drop in both metals was observed. Tissue concentrations were highest for the Patapsco River, Magothy River and Herring Bay collection areas. In 1990, the Patapsco River blue crabs had substantially higher concentrations of nickel than crabs compared to the other collection areas.

The observed 1990 blue crab tissue concentrations were not of concern because they fall well below levels established for the protection of human health. Concentrations of aldrin, alpha-BHC, chromium, dacthal, DDD, DDE, DDT, dieldrin, endosulfan, endrin, gamma-BHC, hep-

## Maryland Oyster Tissue Zinc Concentration Trends



**Figure 30.** Concentrations of zinc in oyster tissue in the Maryland portion of Chesapeake Bay from 1974-1990. West Chesapeake includes the Magothy, Severn, South, West, and Rhode rivers and the mainstem Bay from Herring Bay to Drum Point. Sources: Eisenberg and Topping 1981; Garreis and Pittman 1981a, 1981b, 1982; Garreis and Murphy 1986a, 1986b; Maryland Department of the Environment, unpublished data (d); Murphy 1990.

tachlor, heptachlor epoxide, hexachlorobenzene, methoxychlor, mirex, and toxaphene were not detected in blue crab tissue during the 1990 survey.

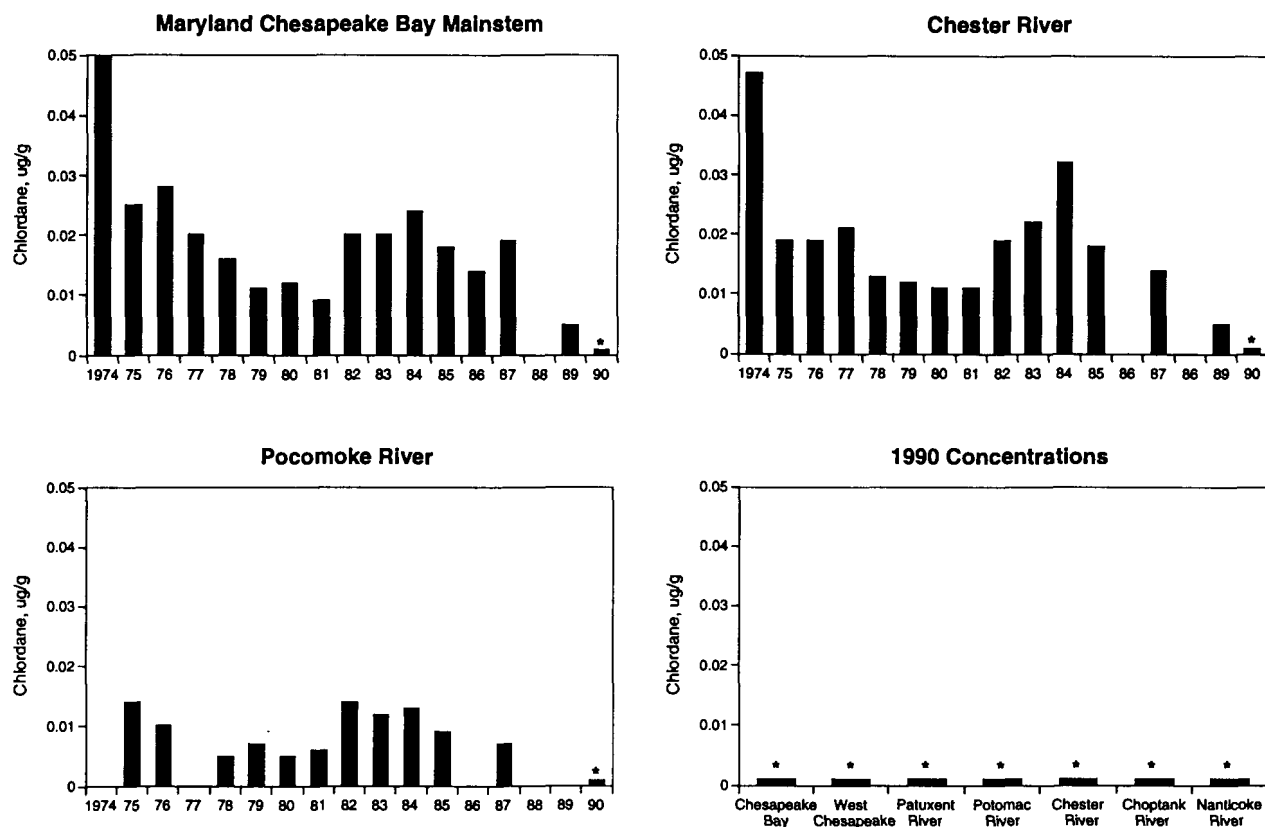
### Virginia

Through Virginia's oyster tissue contaminant monitoring program, samples from 47 sites were analyzed for heavy metals and those from 24 sites for pesticides. Recognizing the relatively high detection limits (e.g., 0.1 ppm for organochlorines, 0.5 ppm for pentachloroanisole, and 1.0 ppm for PCBs), no pesticides have been found above these limits since the late 1970s (Chesapeake Bay Program 1993b; Virginia Department

of Health, unpublished data). Since the early 1970s, metal concentrations in Virginia oysters were as follows:

- **Arsenic:** Concentrations ranged from 0.01 ppm to 2.57 ppm, with an average 1.0 ppm and no readily discernible trend.
- **Cadmium:** Concentrations ranged from 0.2 to 1.6 ppm with higher concentrations observed in shellfish collected from lower salinity stations.
- **Chromium:** Concentrations were normally <1 ppm although some data were high with

## Maryland Oyster Tissue Chlordane Concentration Trends



**Figure 31.** Concentrations of chlordane in oyster tissue in the Maryland portion of Chesapeake Bay from 1974-1990. West Chesapeake includes the Magothy, Severn, South, West, and Rhode rivers and the mainstem Bay from Herring Bay to Drum Point. Bars marked with an asterisk (\*) are concentrations below the detection limit. Sources: Eisenberg and Topping 1981; Garreis and Pittman 1981a, 1981b, 1982; Garreis and Murphy 1986a, 1986b; Maryland Department of the Environment, unpublished data (d); Murphy 1990.

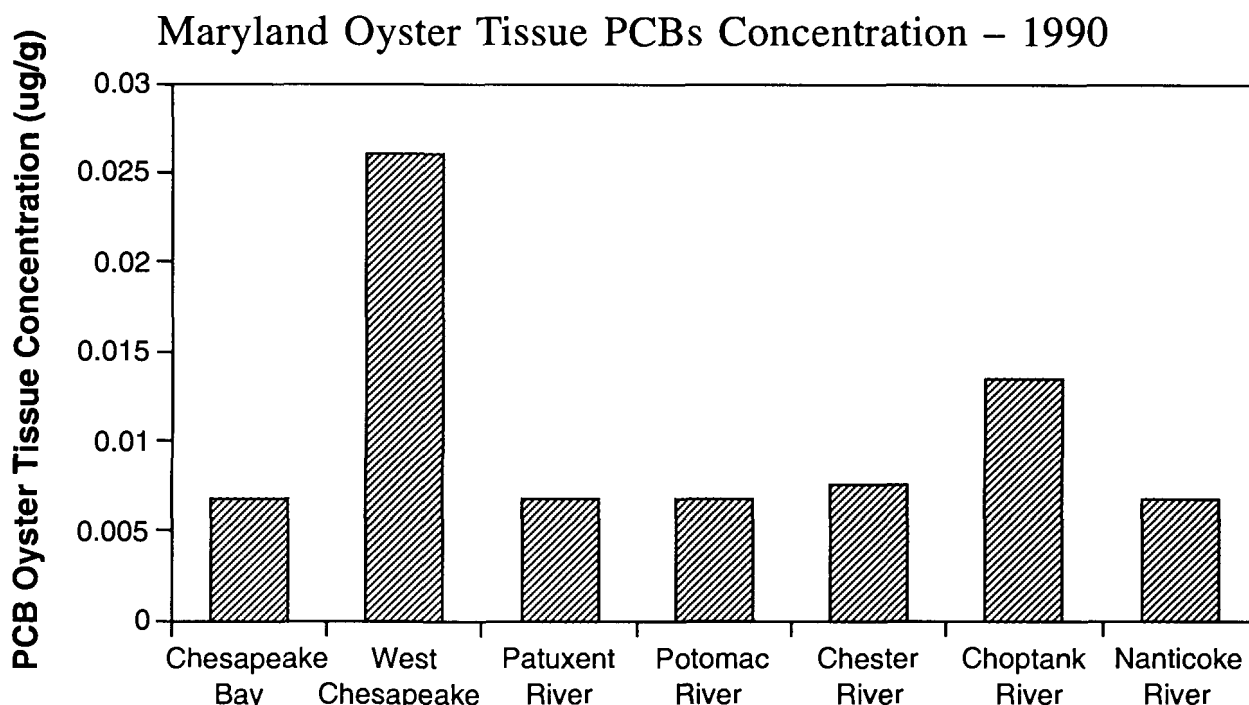
several questionable concentrations reaching 92 ppm.

- **Copper:** Concentrations ranged from 7.4 ppm to 156 ppm with higher concentrations in shellfish collected from lower salinity stations and James River stations.
- **Lead:** Concentrations ranged from <0.2 ppm to 2.0 ppm with no readily discernible trend.
- **Zinc:** Concentrations ranged from 208 ppm to 1,701 ppm (one reported value of 14,000 ppm) with higher concentrations in shellfish

collected from lower salinity stations and James River stations.

The primary sites of concern in Virginia are the Elizabeth River and Little Creek, especially for organic chemical contaminants (i.e., polycyclic aromatic hydrocarbons and their breakdown products) in blue crabs [46, 63]. These two areas are classified as "prohibited" under the National Shellfish Sanitation Program (Table 44; Figure 24). Oysters and clams cannot be taken for human consumption or for relay or depuration. Large numbers of blue crabs are routinely harvested, however, from the Elizabeth River and some from Little Creek.





**Figure 32.** Concentrations of PCBs in oyster tissue collected from the Maryland portion of Chesapeake Bay in 1990. West Chesapeake includes the Magothy, Severn, South, West, and Rhode rivers and the mainstem Bay from Herring Bay to Drum Point. Source: Maryland Department of the Environment unpublished data (d).

## FINDINGS AND CONCLUSIONS

Finfish and shellfish tissue contaminant concentrations throughout the Chesapeake Bay and its tidal tributaries have declined significantly since the 1970s for several metals, pesticides, and organic chemical contaminants. Similar downward trends in tissue concentrations have been observed in the non-tidal portions of the Bay basin. Concentrations of some metals, however, show recent increasing trends in concentrations.

The highest levels of shellfish and finfish contamination were observed at Chesapeake Bay stations in the northern Bay and the Elizabeth River. In some cases, these chemical contaminant concentrations were not as high as those seen

in the most impacted parts of the country; in other cases, they do reach levels comparable to national median concentrations.

Based on the comparisons made with areas having recognized finfish tissue contamination problems across the country, it appears that tissue contaminant concentrations of some chemicals in Chesapeake Bay finfish are not as high as maximum concentrations measured in the northeast states or the Great Lakes. A few chemicals in areas with existing fish consumption restrictions in place—chlordane in Back River and PCBs in the Shenandoah River—show higher concentrations comparable to other fish contaminant problem areas in the country.

### Box 7. Sources of information on Chesapeake Bay finfish and shellfish tissue contamination

Chesapeake Bay Finfish/Shellfish Tissue Contamination Critical Issue Forum Proceedings [46]  
 Comprehensive Review of Selected Toxic Substances - Environmental Samples in Virginia [289]  
 Maryland Reports on Finfish Tissue Contamination [88]  
 Maryland Reports on Shellfish Tissue Contamination [84,85,86,87,207]  
 NOAA National Status and Trends Program Reports [209,211,215,216]  
 State of the Chesapeake Bay - Second Annual Monitoring Report Compendium [180]

Within the Chesapeake Bay basin, existing bans or advisories on finfish/shellfish consumption focus primarily on bottom-feeding finfish contaminated with chlordane, dioxin, mercury, and/or PCBs. Past fish consumption bans (Kepone in the James River) or restrictions (dioxin in the Potomac River within Maryland) were lifted once tissue contaminant concentrations fell below health advisory standards. Outside of these areas, the available tissue data indicate no cause for human health concerns. A more complete assessment of Bay finfish tissue contamination problems is not possible at this time due to areas with no tissue data, lack of action levels for a wide range of chemical contaminants and an uncertain relationship between tissue concentrations and ecological impacts.

## Wildlife Contamination

The critical issue forum on Chesapeake Bay wildlife contamination, held in November 1991, focused on a critical review of data and information on the effects of exposure and uptake of chemical on Chesapeake Bay basin birds, mammals, reptiles, and amphibians [44]. Much of the data and information presented at the forum was extracted from a comprehensive review by Heinz and Wiemeyer [144], discussing the impacts of chemical contaminants on Chesapeake Bay target waterfowl, raptor, and wading bird species. This review was originally published in *Habitat Requirements for Chesapeake Bay Living Resources - Second Edition* [83]. Findings from the forum and recent studies of biomarkers and contaminants in birds and muskrats are summarized in this report.

### BIRDS

Little doubt remains that organochlorine pesticides and possibly other chemicals caused adult mortality and reproductive impairment in raptors, waterfowl, and wading birds in the Chesapeake Bay in the recent past (Table 45). Lead poisoning, from the ingestion of lead shot used by hunters, also may have reduced survival. Various environmental contaminants have adversely im-

pacted those bird populations that use the Chesapeake Bay by reducing survival and reproductive success.

Given the difficulty in finding birds killed by chemical contaminants and the irregular nature of the reporting process for notifying authorities of wildlife mortalities, it is likely that many more birds died from exposure to chemical contaminants than were reported. The major classes of chemicals of concern are organochlorines (including pesticides such as DDT and its metabolite DDE, dieldrin, and Kepone), metals (principally lead and cadmium), oil, organophosphorus and carbamate insecticides (such as Abate and Furadan which are cholinesterase inhibitors), herbicides, and PCBs.

### Pesticides/Organic Compounds

Dieldrin and carbofuran have caused mortality in several bird species in the Chesapeake Bay region (Table 45) [18, 62, 164, 205, 222, 241, 246, 247]. Organochlorine pesticides probably had a greater impact on bird reproduction than on adult survival. DDE was largely responsible for the decline of bald eagle reproduction beginning in the 1950s and continuing into the 1970s (Table 46) [229, 303].

Osprey populations began to decline in the Chesapeake Bay in the 1950s and did not start to recover until the early 1970s (Table 47) [4, 152, 243, 244, 329]. In osprey eggs, DDE has been closely associated with eggshell thinning and also appeared responsible for negative effects on reproduction [330]. Concentrations of organochlorine pesticides generally declined in the tissues of ospreys found dead around the Chesapeake Bay during the 1970s and early 1980s, while PCB concentrations remained unchanged [333]. Kepone may have also affected avian reproduction in the Chesapeake Bay [159].

Compared to DDE concentrations in black ducks from other regions, eggs from the Chesapeake Bay were fairly free of this chemical contaminant. It is unlikely that organochlorine pesticides or PCBs have posed a hazard to black

**Table 45.** Summary of Chesapeake Bay basin wildlife contamination findings—birds

Species	Toxic Substance	Observed Concentrations/Effects	Source
Cattle egret, great blue herons	Dieldrin	Likely cause of death of individuals of both species.	Ohlendorf 1981
Bald eagles	Dieldrin	Likely cause of death of Chesapeake Bay eagles.	Reichel et al. 1969 Mulhern et al 1970 Belisle et al 1972 Cromartie et al 1975 Prouty et al 1977 Kaiser et al 1980 Reichel et al 1984
Bald eagles, American kestrels, red-tailed hawks	Carbofuran	Associated with the death of individuals of these species.	Chesapeake Bay Program 1992b
Bald eagles	DDE	According to a national survey, the highest levels were found in individuals from Chesapeake Bay region.	Wiemeyer et al 1984
Peregrine falcon	DDE	High concentrations resulted in failure of nests in Chesapeake Bay region.	Peakall et al 1975
Osprey	DDE	Believed responsible for Chesapeake Bay population declines.	Wiemeyer et al 1988
Barn owl	DDE	Fifteen percent of population on Maryland side of lower Potomac River contained levels of DDE high enough to impact reproduction.	Klaas et al 1978
Mallard	Abate	Reproductive impairment at levels of 1 ppm on a dry weight basis.	Franson et al 1983
Great blue heron	Kepone	Residues ranging from 2.4 to 36 ppm (wet weight) in livers of individuals from Hog Island Wildlife Refuge were detected.	Huggett and Bender 1980
Bald eagle	Kepone	Elevated levels found in tissues and eggs of individuals collected from the James River region.	Stafford et al 1978 Wiemeyer et al 1984 U.S. Fish and Wildlife Service 1990
Bald eagle	Kepone	Loss of all breeding pairs in James River area (1975-1978) may have been due to kepone contamination.	U.S. Fish and Wildlife Service 1982
Osprey	Kepone	Eggs from areas near James River contained elevated levels.	Stafford et al 1978 Wiemeyer et al 1988
Bald eagle	DDE, Dieldrin, PCBs	Concentrations of DDE (10 ppm), dieldrin (1 ppm), and PCBs (25 ppm) were found in eggs collected from Chesapeake Bay area between 1973-1979.	Chesapeake Bay Program 1992b

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

**Table 45 (con't.)** Summary of Chesapeake Bay basin wildlife contamination findings—birds

Species	Toxic Substance	Observed Concentrations/Effects	Source
Bald eagle	DDE, Dieldrin, PCBs	High levels of dieldrin (> 4 ppm) were responsible for mortality of individuals found in the Chesapeake Bay region.	Mulhern et al. 1970 Belisle et al. 1972 Cromartie et al. 1975 Prouty et al. 1977 Kaiser et al. 1980 Reichel et al. 1984 U.S. Fish and Wildlife Service 1982 U.S. Fish and Wildlife Service 1990
Bald eagle	Carbamate, organophosphorus pesticides	Implicated in the mortality of individuals in the Chesapeake Bay region.	U.S. Fish and Wildlife Service 1990
Osprey	DDE/Dieldrin, PCBs	Eggs collected from Chesapeake Bay area in 1960s and 1970s contained approximately 3 ppm DDE and 3-10 ppm PCBs.	Wiemeyer et al. 1975 Weimeyer et al. 1988
Osprey	Organochlorine pesticide	Concentrations in tissue of individuals found in Chesapeake Bay during 1970s and 1980s declining.	Wiemeyer et al. 1987
Canvasback	Organochlorine pesticides, PCBs	Levels detected in individuals collected from Chesapeake Bay in 1973 and 1975 were safe relative to those known to affect survival and reproduction.	White et al. 1979
Black ducks	DDE	Levels found in eggs collected from Chesapeake Bay area were low, relative to other areas (i.e., New York, New Jersey, Massachusetts).	Reichel and Addy 1968
Wood ducks, Mallards, Black ducks, Pintails		Ingested lead (from lead shot) was considered probable cause of elevated levels in livers of individuals from the Chesapeake Bay basin.	Scanlon et al. 1980 DiGiulio and Scanlon 1984
Osprey	DDE	Median DDE residues in eggs from Glenn L. Martin Refuge in Maryland in 1986 was greater than the value associated with 10% eggshell thinning (2.0 ppm), but below the value associated with a production rate of 1.0 young per nest.	Wiemeyer et al. 1988
Bald eagle	DDE, DDD + DDT, dieldrin PCBs, mercury	Eggs failing to hatch collected in Maryland and Virginia from 1980-1984 contained geometric mean concentrations of 4.4 ppm DDE, 0.42 ppm DDD + DDT, 0.31 ppm dieldrin, 14 ppm PCBs, and 0.07 ppm mercury.	Audet et al. 1992
Peregrine falcon	DDE, heptachlor epoxide, PCBs, oxychlordane	One egg collected on South Marsh Island, Maryland contained 14 ppm DDE, 0.36 ppm heptachlor epoxide, 0.75 ppm oxychlordane and 8.2 ppm PCBs.	Gilroy and Barclay 1988
Source: Chesapeake Bay Program 1992b; Funderburk et al. 1991.			

**Table 46.** Chesapeake Bay region bald eagles contamination and population timeline.

<b>Pre-European Contact:</b>	As many as 3,000 pairs in Chesapeake Bay area.
<b>1936:</b>	Average young per nesting attempt is 1.6 young.
<b>Late 1940s:</b>	DDT introduced.
<b>1950 - 1970:</b>	Major decline in bald eagle population, primarily due to exposure to organochlorine pesticides.
<b>1962:</b>	Nest production drops to 0.2 young per pair.
<b>1970:</b>	As few as 80-90 breeding pairs (nest failure due to widespread DDT use).
<b>1970s:</b>	Absence of all breeding pairs of bald eagles in the James River area, possibly related to elevated kepone levels.
<b>1973-1979:</b>	Concentrations of DDE, dieldrin, and PCBs in eggs collected from Chesapeake Bay nests were 10 ppm, 1.0 ppm, and 25 ppm, respectively, higher than in any other area in the United States. (To ensure successful reproduction, eggs should contain no more than 2 ppm DDE, 0.3 ppm dieldrin, and 5 ppm PCBs.)
<b>1980-1984:</b>	Significant drop in DDE, dieldrin, and PCBs concentrations to 4.5 ppm, 0.3 ppm, and 15 ppm, respectively.
<b>1985:</b>	Total of 185 breeding pairs in Maryland and Virginia.
<b>1992:</b>	Total of 152 occupied nests, 146 active nests, 112 successful nests, and 185 new young in Maryland.

Sources: Fraser et al. 1991; Heinz and Wiemeyer 1991; U.S. Environmental Protection Agency, 1993a.

ducks, at least since the egg surveys began [140, 179, 248].

Wing surveys showed that black ducks from the Chesapeake Bay region contained lower concentrations of most organochlorine pesticides and PCBs than black ducks from states such as Massachusetts, New York, and New Jersey. Moreover, organochlorine pesticides and PCBs have steadily declined in black duck wings collected in the Chesapeake Bay region [37, 142, 143, 240, 326, 328].

Surveys of PCBs and organochlorine pesticides in the brains and carcasses of wading birds found dead along the Chesapeake Bay and its tributaries were conducted in the late 1960s and 1970s. Concentrations of these chemical contaminants in great blue herons, green-backed

herons, and snowy egrets were too low to have been the cause of death. Residues of PCBs and organochlorine pesticides in the eggs of green-backed herons and cattle egrets from the Potomac River were below levels believed to affect reproduction (Ohlendorf et al. 1979). In a more recent survey of the first nesting colony of double-crested cormorants in Chesapeake Bay, metals and organochlorine residues in eggs were below levels considered harmful [145].

### Metals

Various metals, including chromium, copper, zinc, arsenic, cadmium, mercury, and lead, do not appear to have had an adverse effect on Chesapeake Bay ospreys or bald eagles. Concentrations in tissues of birds found dead around the Bay were generally at background levels [333, 334].

**Table 47.** Chesapeake Bay region ospreys contamination and population timeline.

<b>1950 - 1970:</b>	Organochlorine pesticide accumulation in osprey tissue increases.
<b>1950s:</b>	Osprey numbers begin to decline.
<b>1960:</b>	Production rate necessary for population stability is 0.95 - 1.3 year per female.
<b>1960:</b>	Shell thickness up to 35% in some areas, >15% thickness, egg likely to break. DDE (a DDT metabolite) most closely associated with eggshell thinning.
<b>1960s-1970s:</b>	Eggs contained 3 mg/kg DDE, 3-10 mg/kg PCBs.
<b>1966-1971:</b>	Nest productivity below level necessary to sustain population.
<b>1972:</b>	DDT banned.
<b>1970s-1980:</b>	Organochlorine pesticide concentrations in osprey tissue declined, PCBs remain unchanged. Osprey numbers begin to increase.
<b>1980s:</b>	Over 2,000 pairs in Chesapeake Bay area, representing 20% of the Nation's total.

Sources: Reese 1991; Heinz and Wiemeyer 1991.

Except for sea ducks, canvasbacks had the highest concentrations of cadmium in the liver and among the highest in the kidney. Lead, zinc, and copper concentrations in the canvas back were similar to other ducks and were not considered harmful [69]. Black ducks and other dabbling ducks generally had higher lead concentrations than sea ducks and diving ducks, attributable to the higher densities of spent shot in areas inhabited by the dabbling ducks. Cadmium, zinc, and copper in black ducks were below concentrations believed to be harmful to birds [69]. Lead was the only metal in wood ducks that was sufficiently high to be associated with sublethal impacts such as physiological changes [69, 268].

In a review of contaminant effects on birds in the Chesapeake Bay, Ohlendorf and Fleming [221] stated, "In the Chesapeake Bay, high concentrations of cadmium and lead in sea ducks, lead in dabbling ducks, and DDE in some ospreys and bald eagles are the current avian contaminant issues." In addition, recent isolated examples of direct toxic impacts of chemical contaminants on

individual species of birds have been recorded. These include:

- Bald eagle deaths caused by consumption of either illegally poisoned baits or terrestrial animals which had ingested carbofuran;
- Diazinon consumption effects on mallards, doves, and robins in Virginia urban areas; and
- Elevated DDE tissue concentrations in peregrine falcons and bobwhite quail.

The indirect effects of chemical contaminants on bird habitat and food sources (i.e., the loss of submerged aquatic vegetation) caused by excess nutrients, suspended sediment, and, possibly, herbicides are probably more serious than the direct impact of chemical contaminants on birds [230].

## **MAMMALS**

Whether populations or communities of wild mammals within the Chesapeake Bay basin have been or are now being adversely affected by

exposure to chemical contaminants is a question that cannot yet be fully answered due to lack of data [44]. Elevated residues of cadmium, lead, pesticides, PCBs, and polycyclic aromatic hydrocarbons have been reported in selected mammals but the data are very limited (Table 48). There appear to be at least two possible issues of concern: the potential for adverse impacts on mink populations due to exposure to PCBs and the mortality of mammals—especially species of fox size and smaller—that results from primary or secondary poisoning by anti-cholinesterase agricultural chemicals.

### REPTILES

The adverse effects of chemical contaminants on reptiles both in the Chesapeake Bay basin and elsewhere are not well known [44]. The effects of PCBs, dioxins, or furans on reptiles have never been firmly established although limited evidence implies that these compounds could cause both deformities and delayed hatching in the eggs of the snapping turtle [28]. A study of the effects of four organophosphorus pesticides on a lizard showed that these effects were more similar to birds and mammals than amphibians and fish [128]. No other studies of the effects of cholinesterase-inhibiting pesticides on reptiles are known.

Reptiles, particularly turtles, can accumulate metals from metals-contaminated environments but there are no documented cases of wild reptiles dying from metal poisoning [1, 220]. The physiological and behavioral responses of reptiles to metal exposure have not been determined.

### AMPHIBIANS

Overall, insufficient information exists on the current status of amphibian populations. There is very limited research or residue analysis col-

lected regionally from which to assess either the actual or potential adverse effects from chemical contaminants on amphibians within the Chesapeake Bay [44]. Amphibians, however, are sensitive to metals and organochlorine pesticides.

Frogs, bullfrogs, and toads collected on a relatively undisturbed wildlife refuge in Maryland were analyzed for metal residues. Adults accumulated high concentrations of copper whereas tadpoles accumulated lead, zinc, copper, cobalt, cesium, strontium, iron, magnesium, and, to a lesser extent, cadmium [129].

### FINDINGS AND CONCLUSIONS

Although organochlorine pesticides and, perhaps PCBs affected birds throughout the Chesapeake Bay basin in the past, there is little evidence that they are still causing significant adverse impacts. Continued increasing population trends in two of the bird species historically impacted by these toxic chemicals—bald eagle and ospreys—indicate that the severe wildlife contamination problems once present throughout the Bay basin have diminished. Waterfowl, raptor, and wading bird contamination issues in Chesapeake Bay basin have moved from severe basinwide impacts due to elevated concentrations of a number of chemical contaminants to a much more limited set of species, chemical type, and region-specific issues. Existing data are too limited to determine whether chemical contaminants are adversely impacting Chesapeake Bay populations of mammals, reptiles, and amphibians.

*Box 8. Sources of further information on Chesapeake Bay wildlife contamination*

*Chesapeake Bay Wildlife Contamination Critical Issue Forum [44]*

*"Effects of Contaminants on Birds" in Habitat Requirements for Chesapeake Bay Living Resources, 1991 Edition [144]*

**Table 48.** Summary of Chesapeake Bay basin wildlife contamination findings—mammals.

Species	Toxic Substance	Observed Concentrations/Effects	Source
Raccoons	Kepone	Elevated residues reported in individuals collected in James River region.	Bryant et al. 1978
White footed mouse	Kepone	Elevated residues reported in individuals collected in James River region. Levels in mice collected at the reference site were significantly lower.	Terman and Hugget 1980
Little brown bats	DDE, dieldrin, PCBs	Mean maximum concentrations of 1.80 ppm DDE, 1.01 ppm dieldrin, and 3.22 ppm PCBs reported in individuals collected from North East, Maryland.	Clark and Prouty 1976
Big brown bats, little brown bats	DDE, dieldrin, PCBs	Big brown bat carcasses collected in Laurel, Maryland contained concentrations of DDE (5.32 ppm) and PCBs (4.99 ppm). Little brown bat carcasses contained concentrations of 3.0 ppm DDE and 11.6 ppm PCBs.	Clark and Prouty 1976
Mink	PCBs, DDE, oxychlordane, heptachlor epoxide, dieldrin	Mean PCB concentrations in individuals collected in Maryland were at levels known to prevent reproduction. Mean concentrations of the other constituents were less than 0.5 ppm (wet weight).	O'Shea et al. 1981
Atlantic bottlenose dolphin	DDE, dieldrin, PCBs	The blubber in individuals collected from Maryland and Virginia contained a maximum of 80 ppm (lipid weight) DDE, 6 ppm dieldrin, and 195 ppm PCBs.	Kuehl et al. 1991
Muskrat	Nickel, selenium	Reduced body and spleen weights through depression of immunological function was likely caused by nickel (00.5 ppm dry weight—lower Elizabeth River) and selenium (5.31 ppm—upper Elizabeth River).	Halbrook 1990
River otters	Lead, cadmium	Median concentrations of lead in bone and cadmium in kidneys in individuals collected in the Virginia portion of Chesapeake Bay were 2.95 ppm lead (dry weight) and 0.15 ppm cadmium (dry weight).	Anderson-Bledsoe and Scanlon 1983
Mink	Lead	Individuals from areas adjacent to Chesapeake Bay contained lead concentrations $\geq 3$ ppm (dry wt.) in their bones and cadmium at $\geq 2$ ppm (dry wt.) in kidneys.	Ogle et al. 1985
Feral house mice	Methomyl (Lannate)	Significant depression (11-12%) of brain cholinesterase activity in individuals occurred just after spraying near Chesapeake Bay.	Montz et al. 1983



**Table 48 (con't).** Summary of Chesapeake Bay basin wildlife contamination findings—mammals.

Species	Toxic Substance	Observed Concentrations/Effects	Source
Raccoons (13) Opossums (4) Red foxes (4) Muskrats (1) White tailed deer(1) River otter (1) Squirrel (1)	Carbofuran	Responsible for the mortality of these individuals in Chesapeake Bay counties. Number of actual individuals listed in parentheses.	Chesapeake Bay Program 1992b
Gray fox (1) Red fox (1)	Parathion	Responsible for the mortality of one individual of each species in Chesapeake Bay counties.	Chesapeake Bay Program 1992b
Raccoon (1)	Famphur	Responsible for the mortality of one individual of this species in Chesapeake Bay area.	Chesapeake Bay Program 1992b
Raccoon (1)	Avicide (unidentified)	Responsible for the mortality of one individual of this species in Chesapeake Bay area.	Chesapeake Bay Program 1992b
Muskrats	PAHs	Carcasses collected in the upper Elizabeth River area had detectable levels of PAHs (1-6 compounds). Individuals collected in the upper and lower Elizabeth River had PAH concentration >0.03 ppm (dry wt.). Individuals from the lower Elizabeth River had greater liver microsomal enzyme activity. Twenty-seven metals were detected in muskrat kidneys.	Halbrook and Kirkpatrick 1991
Muskrat	PAHs	DNA adducts were detected in individuals collected from the Elizabeth River and Nansemond River areas. The greatest concentration was found in one individual from the Nansemond River (236 nmol per mol). DNA adducts form as a result of exposure to DNA-reactive Carcinogens (i.e., PAHs) and are believed to be an initiating event in cancer development.	Halbrook et al. 1992

Source: Chesapeake Bay Program 1992b.



# STATE REGULATORY AND MANAGEMENT PROGRAMS

The 1989 Basinwide Toxics Reduction Strategy was written “to achieve a reduction of toxics consistent with the Water Quality Act of 1987” and to build upon existing regulatory and management programs already in place. Many of the environmental responses and trends described previously are a direct or indirect result of these state and federal programs. Summaries of these programs are described below and in greater detail in Appendix A to provide the reader with a better understanding of these ongoing programs.

## Pennsylvania

### Water Quality Standards Program

The Pennsylvania Department of Environmental Resources regulates chemicals through codified chemical-specific and narrative requirements in chapters 16 and 93 of the Pennsylvania Code. These requirements serve as the basis for developing water quality-based effluent limitations which are incorporated into National Pollutant Discharge Elimination System (NPDES) permits and other regulatory actions protecting water uses. The major provisions are as follows:

- Prohibit discharges of chemicals in toxic amounts.
- Specify scientific procedures for the development of both threshold and non-threshold human-health based criteria.
- Specify a risk management level of one excess cancer in a population of one million over a 70-year lifetime for the control of carcinogens.
- Provide guidelines for the development of fish and aquatic life criteria.

- Specify analytical procedures for criteria implementation.
- Specify appropriate design conditions.
- Provide listings of specific numeric criteria and analytical detection limits.

Pennsylvania’s Department of Environmental Resources reviews Chapter 93 and revises it, if necessary, during each Triennial Water Quality Standards review mandated by Section 303(c) of the Clean Water Act. The Pennsylvania Environmental Quality Board approved the most recent Triennial Review revisions on August 17, 1993. Upon completion of the state regulatory review process they will be forwarded to EPA for approval.

The Department of Environmental Resources also reviews Chapter 16, which includes listings of numeric criteria and analytical detection limits, at least annually and often more frequently. Since its initial adoption in 1989, Chapter 16 has been revised four times; a fifth revision is in preparation. There are 145 chemicals for which numeric standards have been established in Chapter 16.

The Department of Environmental Resources conducts an ongoing water quality assessment program which includes the collection and evaluation of information regarding waste sources, water quality, water uses, and criteria that are used to establish cause and effect relationships. A Water Quality Assessment Summary, an abbreviated record of the analysis of water quality information, is completed for each assessment activity.

The most recent assessment information (from the 1993 305(b) update) shows that just over 956 stream miles are impacted by chemical contami-

nants in the Susquehanna River basin. Of these, nearly 894 miles (93.5 percent) are affected by metals from abandoned mine drainage—a major problem in portions of the North Branch Susquehanna River and the upper West Branch Susquehanna River. In addition, about eight miles of degradation are attributed to active mining. Only about 54 miles are affected by chemical contaminants from other sources. These include segments with fish consumption advisories, impacts from contamination at Texas Eastern compressor stations, volatile organic compounds, and metals mobilized by acid rain.

## **Point Source Programs**

### ***PERMITTING PROGRAM***

Pennsylvania is an NPDES-delegated state and carries out NPDES permitting, compliance, and enforcement programs in accordance with state and federal regulations and the memorandum of agreement between the Department of Environmental Resources and the EPA. For over a decade, toxics control and management have composed a major portion of the state's NPDES program and are being carried out pursuant to the Bureau of Water Quality Management's Toxics Management Strategy. The Toxics Management Strategy is the basis for writing NPDES permits for all point sources including the 304(l) discharges. Appendix A provides more detailed descriptions of the Toxics Management Strategy and toxics evaluation procedures.

Generally, all NPDES permit renewal actions are made on a watershed basis. The Department of Environmental Resources' watershed permitting process focuses on the highest water quality improvement priorities while ensuring that all permits are reviewed and renewed over a five-year period.

### ***STORMWATER MANAGEMENT PROGRAM***

Pennsylvania is implementing the federal stormwater permitting regulations (40 CFR

122.26). The Department of Environmental Resources has issued two stormwater general permits—one for industrial activities and one for construction activities. The permits for stormwater discharges from industrial activities are handled by the Department's Bureau of Water Quality Management with the majority granted through these general permits. Individual permits are required for certain activities, however, such as discharges to designated anti-degradation waters, Superfund Amendment and Reauthorization Act (SARA) Title III facilities that exceed the reportable quantities for listed chemicals, and stormwater discharges containing or expected to contain chemicals.

### ***BIOMONITORING PROGRAM***

Pennsylvania's point source control program is a chemical-specific approach to limiting chemicals in wastewater discharges. As a result, less emphasis has been placed on whole effluent toxicity testing as a control measure. Although biomonitoring is viewed as an important aspect of toxics management, its role has been limited due to resource constraints. In cooperation with EPA Region III, Pennsylvania has identified a select number of cases for implementing whole effluent toxicity testing requirements. In these cases, the Department of Environmental Resources incorporates the whole effluent testing requirements in the NPDES permits with EPA interpreting the results of these tests. Follow-up actions required as a result of the testing are coordinated between the department and the EPA. Pennsylvania plans to continue seeking resources to expand its use of biomonitoring as a toxics control measure.

### ***PRETREATMENT PROGRAM***

Pennsylvania has not been delegated primacy for the pretreatment program. However, the Bureau of Water Quality Management is actively participating in the program in a number of ways. Any pretreatment problems identified as a result of Department of Environmental Resources field

activities are referred to EPA for action. Forty-three facilities in Pennsylvania's portion of the Chesapeake Bay basin have or are required to have pretreatment programs in place.

In addition to consultation with EPA Region III on its implementation actions, the Department of Environmental Resources, in cooperation with the Water Pollution Control Association of Pennsylvania, has been sponsoring pretreatment forums around the state for pretreatment coordinators, treatment plant operators, and consultants. The Department of Environmental Resources' Operator Outreach Program provides on-site pretreatment assistance to municipalities around the state. The future of a request for delegation of the pretreatment program will depend on the availability of adequate staff resources to implement a meaningful program.

## **Nonpoint Source Programs**

### ***PESTICIDE MANAGEMENT PROGRAM***

Pennsylvania has controlled pesticide use through a program implementing the 1987 amendments to the Pennsylvania Pesticide Control Act. The program requires licensing of all pesticide applicators. Commercial and public applicators must be licensed for application of all pesticides, while private applicators, such as farmers, must be licensed to apply restricted use pesticides. Over 25,000 applicators are licensed under this program. To become licensed, an applicator must pass an examination which insures that the applicant has the required knowledge for pesticide use in conformance with label requirements. Once licensed, an applicator must follow label requirements and receive update training or face license revocation.

Pennsylvania is actively promoting an integrated pest management program. The program is designed to encourage integrated pest management using mechanical, cultural, and chemical control measures to develop pest control strategies. The foundation of the integrated pest

management program is an agreement between the Pennsylvania Department of Agriculture and Pennsylvania State University. The program is promoted through educational efforts using audiovisual presentations and technical handouts; the program techniques and results have received much media attention. Over \$1 million in integrated pest management research projects have been funded over the past four years. This research has resulted in successful measures for reducing or eliminating pesticide use on tomato and poinsettia crops and the establishment of a U.S. Department of Agriculture cost share program to encourage the adoption of crop management services. By the end of 1992, an estimated 400,000 acres were subject to integrated pest management practices.

### ***STORM WATER MANAGEMENT PROGRAM***

The Pennsylvania Storm Water Management Act, implemented by the Department of Environmental Resources' Bureau of Dams, Waterways, and Wetlands, requires counties to prepare watershed stormwater management plans, considering the hydrologic and hydraulic effects of changes in land use including nonpoint source pollution. The plans must identify water quality controls associated with nonpoint source pollution; standards and criteria are implemented by local municipalities through the adoption of codes and ordinances.

## **Hazardous Waste Management Programs**

### ***RCRA PROGRAM***

Residual and hazardous waste regulations have been developed as part of Pennsylvania's Resource Conservation and Recovery Act (RCRA) program to focus on source reduction as a means to prevent waste. In the waste management hierarchy, source reduction has the highest priority followed by use and reclamation, treatment, and disposal. The hazardous and residual waste

regulations require each generator to develop a source reduction strategy. The generator must specify what actions will be taken to reduce waste, when the actions will be taken, and the reduction expected.

A source reduction strategy manual has been developed to help generators comply with the requirements and to achieve source reduction. The manual includes a discussion of the regulatory requirements, the elements of a comprehensive source reduction program, the means to measure reduction, and the ways to conduct a source reduction opportunity assessment. The Department of Environmental Resources is also developing a technical assistance program to help waste generators implement source reduction programs.

In the future, the Department of Environmental Resources will be training its own staff to identify waste reduction opportunities during inspection and permitting activities. The department may also develop a strategy for targeting technical resources to those waste streams where management capacity shortfalls may exist.

### ***SUPERFUND PROGRAM***

Pennsylvania continues to play an active role in the Federal Superfund Program by cooperating with the EPA at the 99 state sites on the National Priority List. In addition, the Department of Environmental Resources is pursuing remediation at additional hazardous waste sites that are not on the federal list under the auspices of the State Hazardous Sites Cleanup Act enacted in 1988.

To date, eight sites in Pennsylvania have been addressed and removed from the EPA Superfund List—more than any other state. Cleanups by potentially responsible parties have also been started at 16 additional sites on the list. Under the state's Superfund Program, responses have been completed at an additional 29 sites with ten more sites scheduled for remedial action.

## **Air Quality Control Program**

The Department of Environmental Resources requires the application of Best Available Technology to control airborne pollutants, including toxic chemicals, from new sources. In addition, specific policies mandate acceptable levels of air toxic chemicals from municipal and hospital waste incinerators. Permittees for these types of facilities, as well as for coke oven batteries, must perform an air toxics analysis as part of their requirements.

The department plans to implement all of the Clean Air Act requirements for the control of hazardous air pollutants (toxic chemicals) promulgated by the EPA for both new and existing sources. When possible, pollution prevention requirements will be incorporated during the development of the regulations.

## **Maryland**

The State of Maryland has numerous programs to reduce potentially toxic chemicals in the environment. Concerns center on the protection of both human and environmental health. To this end, efforts have focused on the reduction of toxic materials released to the air, land, and water. Since materials released to the atmosphere and deposited on land have the potential to contaminate state waters, all of Maryland's control efforts ultimately benefit water quality.

Maryland's efforts to control releases have been supplemented with several pollution prevention programs. These programs are essential given the problems associated in dealing with potentially toxic chemicals once they are released to the environment. Some of the key programs in Maryland that address the control of potentially toxic chemicals are presented below.

### **Water Quality Standards Program**

Water quality standards established in Maryland are designed to protect all waters for

recreational use and the propagation and growth of a balanced population of fish and wildlife. More stringent classifications have been established for shellfish, recreational (put and take) trout fishing, natural trout propagation, and potable water. The water quality standard for chemicals states that "...waters may not be polluted by chemicals which may be harmful to aquatic life." Numeric criteria for substances of concern have also been established to provide additional protection.

In 1989, Maryland adopted water regulations prohibiting the discharge of chlorine or chlorine compounds to natural trout waters and requiring the dechlorination of any effluent treated with chlorine. Maryland also adopted water quality standards for tributyltin. Specific numeric standards for an additional 27 potentially toxic chemicals were adopted in 1990.

The Maryland Department of the Environment continually assesses the merit and adequacy of the state's water quality standards. The reevaluation process is scheduled to occur every three years in conjunction with the EPA review of the state's water quality program, but can occur more frequently when specific needs are identified.

## **Point Source Programs**

### ***PERMITTING PROGRAM***

The goal of the permitting program is to ensure that state waters meet established criteria, including those established for potentially toxic chemicals. Specific chemical limitations established in the discharge permits, in conjunction with biological monitoring, allow the Department of the Environment to control the discharge of pollutants.

Major and minor dischargers with the potential for releasing chemicals have had requirements incorporated into their permits to conduct acute

and chronic bioassay tests to screen for toxic effects. Facilities with toxic discharges have been required to conduct confirmatory testing and undergo a toxicity reduction evaluation to identify and remove sources within the plant or collection system.

Facilities discharging to waters impacted by chemicals will have their permits modified to include numeric restrictions on pollutants of concern. Permit modifications will be instituted as problems are identified; modifications will also be incorporated as permits are reviewed during the normal permit renewal process (i.e., every five years).

### ***PRETREATMENT PROGRAM***

Approved programs delegating authority to issue pretreatment permits have been established in 17 jurisdictions statewide. These jurisdictions control 31 wastewater treatment plants and regulate wastes from over 260 industrial facilities and numerous smaller facilities. Specific limitations on the discharge of chemicals have been established and applied to each contributing facility. The Maryland Department of the Environment maintains the data for influent and effluent concentrations of chemicals at wastewater treatment plants.

Specific facility discharge limitations will be reevaluated as revised toxic control regulations are implemented. Additional jurisdictions may be required to establish pretreatment programs as wastewater treatment plants and the number of significant industrial facilities increase.

## **Nonpoint Source Programs**

### ***PESTICIDE MANAGEMENT PROGRAM***

The Maryland Department of Agriculture is responsible for regulating the use, sale, storage, and disposal of pesticides. The primary functions of the pesticide management program are to enforce state and federal pesticide use laws and regula-

tions, ensure that pesticides are applied properly by competent individuals, and protect the health of citizens and natural resources. These functions are carried out through five major programs: 1) pesticide applicator certification and training; 2) pesticide use inspection and enforcement; 3) pesticide technical information collection and dissemination; 4) groundwater, worker, and endangered species protection; and 5) special programs.

### ***STORMWATER MANAGEMENT PROGRAM***

Through regulations established in 1983, each county and municipality was required to adopt a stormwater management program by July 1984. The requirements of the program are designed to help meet the goal of maintaining pre-development runoff characteristics, including factors contributing to the transport of chemical contaminants.

A 1988 amendment to Maryland's Stormwater Management Act required that runoff characteristics and water quality be enhanced on redevelopment projects, even if the amount of impervious land did not increase. Stormwater runoff permits are required for these facilities in ten industrial categories, construction sites disturbing more than five acres, and municipalities with populations over 100,000. Maintenance of stormwater control structures is essential in mitigating the effects of stormwater and its associated contaminants.

## **Hazardous Waste Management Programs**

### ***RCRA PROGRAM***

The Resource Conservation and Recovery Act requires numerous controls on the handling of hazardous wastes. The primary intent of the regulations is to prevent the contamination of land and water by toxic pollutants. Control strat-

egies include elements that address the treatment, storage, and disposal of hazardous wastes.

As part of the overall strategy to reduce the generation of hazardous wastes, the Department of the Environment established a Pollution Prevention/Waste Minimization program in 1990. Over 3,000 waste generators have been advised of available technical assistance and the establishment of a clearinghouse to provide information on available reduction processes and technologies. Advanced training for inspectors will help them to identify situations in which waste reduction technologies could be used. Failure of hazardous waste generators to implement waste reduction efforts may result in enforcement actions.

### ***SUPERFUND PROGRAM***

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), or Superfund Law, was created in 1980 to clean up hazardous waste sites to prevent or mitigate the contamination of surface water and groundwater. In addition, it established response requirements for releases or threats of releases of hazardous substances that may endanger public health, public welfare, or the environment. Maryland enacted its own Superfund law in 1984. A total of 450 potential CERCLA sites have been identified in Maryland.

The Department of the Environment has been assessing known waste disposal sites and ranking them according to a grading system which considers the types of wastes present and their impact on the surrounding human population and/or environment. Sites which meet criteria established by the federal government are placed on the National Priority List. Twelve sites have met these criteria and have had imminent hazards abated. Four additional sites have been proposed for the National Priority List; further site restoration at these sites is in progress. Those sites that do not meet the federal criteria but are still con-



sidered hazardous are remediated under the state program. Restoration efforts will continue at the National Priority List sites and the 41 sites currently included on the state list. The restoration of these sites will help prevent the contamination of the state's surface water and groundwater by chemicals.

## **Air Quality Control Program**

Maryland toxic air pollutant regulations were promulgated in 1988 to restrict the emission and subsequent land and water deposition of potentially toxic chemicals. These regulations require that chemical emissions be quantified and reported. This self-monitoring and reporting process places the industry in the position of reporting its discharges to its own management, the Department of the Environment, and the public. A demonstration of no adverse impact on public health must be provided with new sources required to employ toxics-best available control technology. Incorporated in the process is a requirement to evaluate pollution prevention options.

Approximately 400 facilities met the January 1992 regulatory requirements by demonstrating their compliance. Over 1,000 sources are controlled under the state regulations (Figure 33); many of these facilities have made significant reductions in their emissions. The enforcement program associated with this program is expected to bring all facilities into compliance. Some modifications to the state program will be needed to establish compatibility with Title III of the 1990 Clean Air Act Amendments.

## **District of Columbia**

### **Water Quality Standards Program**

The District of Columbia promulgated an extensive set of chemical-specific water quality

standards in 1985. More recently, the district revised its water quality standards for surface water and groundwater. The standards were published as proposed rules on September 7, 1990 and were submitted to a public hearing on June 6, 1991. Due to the significant number of responses and comments from both interested parties and the EPA on the standards for surface waters, standards for groundwater were published separately as Proposed Rulemaking on April 2, 1993. This division allowed the district time to incorporate the comments from the public hearing and discussions between the District of Columbia government and other concerned agencies into the surface water standards.

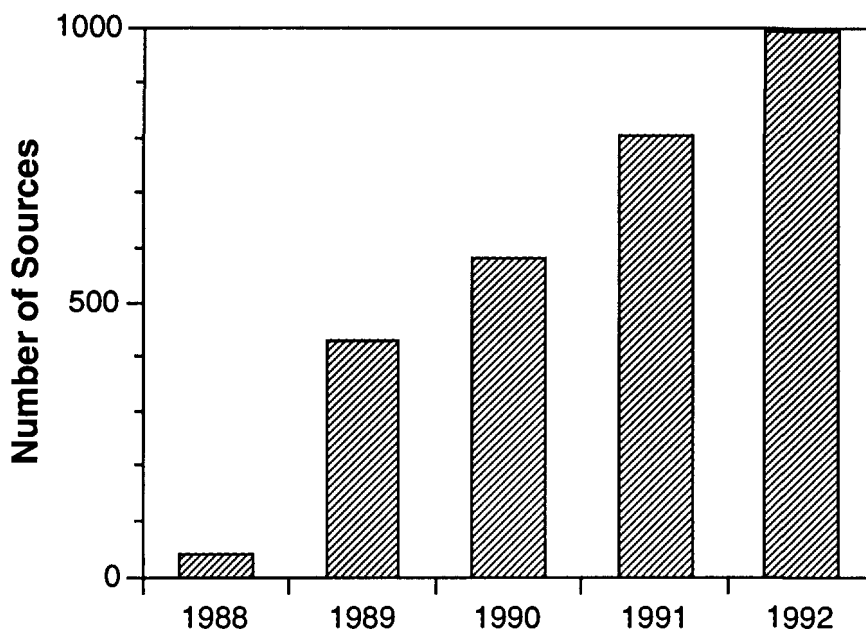
The water quality standards for groundwater were promulgated as Final Rule on July 2, 1993. The water quality standards for surface water were published as Proposed Rulemaking on April 2, 1993. The standards are currently under review for Final Rulemaking by the District of Columbia's Corporation Council. A decision for finalizing the water quality standards for surface water will be made in 1994.

## **Point Source Programs**

### ***PERMITTING PROGRAM***

The major point source discharge in the District of Columbia comes from the Blue Plains Wastewater Treatment Plant. Combined sewer overflows are also a point source of pollution. The District of Columbia's point source program strives to use the best and most cost-efficient technology for the treatment of municipal effluent and combined sewer overflows. The Blue Plains Wastewater Treatment Plant, one of the largest treatment facilities in the country, provides primary, secondary, and tertiary treatment followed by chlorine disinfection and sulfur dioxide dechlorination to eliminate the toxic effects of residual chlorine.

### Air Toxics Sources Regulated in Maryland



**Figure 33.** Number of sources regulated under Maryland's toxic air pollutant regulation from 1988-1992. Source: Maryland Department of the Environment, unpublished data (b).

The Blue Plains Wastewater Treatment Plant serves the District of Columbia, parts of Montgomery and Prince George's counties, Maryland, parts of Fairfax County, Virginia, and several suburban federal facilities. The District of Columbia's share in the current full treatment design flow is 135 million gallons per day.

Presently, the EPA issues NPDES permits for the District of Columbia with review and comments from the District of Columbia government. Regulations were drafted to establish procedures which will allow the District of Columbia to issue discharge permits for point sources within its jurisdiction. These regulations are expected to be finalized in 1994.

#### ***PRETREATMENT PROGRAM***

The District of Columbia Department of Public Works, Water and Sewer Utility Administration manages the program for the pretreatment of industrial waste discharged into the sewer system

and Blue Plains. The District of Columbia promulgated pretreatment regulations in 1986, last amended in 1990. Under these pretreatment regulations, the District of Columbia has issued 42 discharge permits to control metals and other chemicals emanating from industrial dischargers of waste to the sanitary sewer. The District of Columbia has also issued 56 Temporary Discharge Authorizations to individual companies, mostly for groundwater remediation.

#### ***COMBINED SEWER OVERFLOW PROGRAM***

The District of Columbia is currently reevaluating the combined sewer overflow problem to determine control options. As part of this study, chemical contaminants will be identified in the combined sewer overflows. Depending on the results, the District of Columbia may need to develop a program to control chemical contaminants in combined sewer overflows.

## **Nonpoint Source Programs**

### ***PESTICIDE MANAGEMENT PROGRAM***

The main objectives of the district's Pesticide Management Program are to train and certify pesticide applicators in the proper labeling, distribution, disposal, storage, transportation, and safe use and handling of pesticides by:

- assuring compliance with applicable legal requirements related to the distribution, sales, storage, production, transportation, use, application, and disposal of pesticides,
- minimizing the hazards of pesticide use to human health, fish and wildlife, and the environment,
- encouraging non-chemical control methods, such as mechanical, cultural, and biological controls, to reduce the quantity of pesticides used in the district, and;
- continuing to implement civil penalties in the form of Civil Infraction Tickets for those violations of the District Pesticide Law which do not warrant criminal prosecution.

The pesticides program, initiated in 1978, also includes a lawn care initiative, public outreach and educational activities, and groundwater management planning.

### ***INTEGRATED PEST MANAGEMENT PROGRAM***

The District of Columbia's Integrated Pest Management program began in 1992 with surveys targeted at two groups: organizations and businesses registered to apply pesticides in the district; and residential users of pesticides. To educate the public on the benefits of integrated pest management, the district has produced and distributed two pamphlets and created a portable display for use at community functions.

### ***NONPOINT SOURCE MANAGEMENT PROGRAM***

In response to Section 319(h) of the Clean Water Act requirements, the District of Columbia prepared a Nonpoint Source Management Plan in 1989 and submitted it to the EPA. This document provides a district-wide strategy for controlling nonpoint source pollution and describes present and planned nonpoint source pollution abatement projects. One outcome of this plan was the creation of a Nonpoint Source Management Program by the District of Columbia with funding assistance from Section 319(h) funds.

The main goal of the District of Columbia's Nonpoint Source Management Program is to reduce nonpoint source pollution, improving water quality. Because 65 percent of the District of Columbia's surface area is impervious, the Nonpoint Source Management Program targets urban stormwater runoff. The purpose of the Nonpoint Source Management Program is to coordinate these activities, ensuring that limited funds are used efficiently, certain areas of nonpoint source prevention and control are addressed, and high-priority waterbodies are targeted.

### ***STORMWATER MANAGEMENT PROGRAM***

The District of Columbia established the Stormwater Management Program in 1984. The program controls nonpoint source pollution through a regulatory mechanism by ensuring that developers control both the quantity and quality of stormwater runoff from project sites by using best management practices. The program reviews and approves all construction and grading plans submitted to the District of Columbia government for compliance with stormwater management regulations. Engineers also provide technical assistance to developers on the selection of best management practices for a particular site. Enforcement of regulations is through the District of Columbia's Civil Infraction Program

in which inspectors have the authority to issue citations to violators of stormwater management regulations, fines, and stop-orders.

## **Hazardous Waste Programs**

### ***HAZARDOUS WASTE MANAGEMENT PROGRAM***

The District of Columbia's Hazardous Waste Management Program was developed to protect human health and the environment from hazardous waste releases due to improper handling, transportation, storage, and disposal activities pursuant to the District Hazardous Waste Management Act of 1977 and the Resources Conservation and Recovery Act. Disposal of hazardous waste is prohibited in the district; wastes are transported out of the district for disposal. Program activities focus on RCRA grant responsibilities which include program authorization and regulation development, permitting, program administration, waste minimization and pollution prevention, and compliance monitoring and enforcement.

### ***WASTE MINIMIZATION AND POLLUTION PREVENTION PROGRAM***

A revised waste minimization and pollution prevention program is being developed to meet the 1993 Capacity Assurance Plan submittal requirements. This program endorses the national goals of pollution prevention and waste reduction. The technical assistance portion of this program will identify source reduction and recycling opportunities, promote the use of additional waste minimization methods through the distribution of fact sheets, and work toward in-house waste reduction audits for specific industries.

### ***UNDERGROUND STORAGE TANK PROGRAM***

The District of Columbia's Underground Storage Tank Program was established to prevent

and control the leaks and spills that may result from underground storage tanks and contaminate groundwater and subsurface soil. All non-residential underground storage tanks containing gasoline or hazardous materials must be registered, allowing the district to record the location, contents, and condition of storage tanks. All newly installed underground storage tanks are required to be non-corrosive.

## **Air Quality Control Program**

Air pollution control activities in the District of Columbia are authorized by the 1984 amendments to the district's Air Pollution Control Act and the Federal Clean Air Act. The district's air pollution control program develops and implements plans and programs for protecting and managing the district's air resources. This program determines allowable source emissions, issues construction and operating permits, and inspects air pollution sources. It also coordinates and inspects asbestos renovation and demolition and operates and maintains a district-wide ambient air quality monitoring network.

The District of Columbia's air pollution control programs, currently under development, are designed to comply with Title III of the Clean Air Act which requires Maximum Available Control Technology Standards for chemicals in various industrial and commercial source categories.

## **Virginia**

### **Water Quality Standards Program**

Instream water quality standards include both narrative statements that describe general water quality requirements and numeric limits for the specific physical, chemical and biological characteristics of water. Generally, an instream water quality standard is the maximum concentration allowed in the water before unacceptable adverse

effects occur. Past water quality standards focused on the protection of aquatic life, with the exception of standards for public water supplies and groundwater. Recent emphasis has been placed on the protection of human health (as a result of the 1987 amendments to the Clean Water Act), leading to the development of water quality standards for potentially toxic chemicals.

Efforts to address chemical contaminants in Virginia's waters date back to the Kepone contamination of the James River in 1976. In addition to Kepone, the Virginia State Water Control Board adopted other water quality standards in response to identified toxic problems in the Chesapeake Bay area involving specific chemicals.

In March 1992, Virginia's efforts to comply with the Clean Water Act's requirements to adopt water quality standards for chemicals culminated in the adoption of a new section in the state water quality standards specifically addressing chemicals. Included in this section were 41 numeric standards for the protection of aquatic life and 66 numeric standards for the protection of human health. This new section also included definitions of acute and chronic toxicity, an allowance for employing updated EPA information in establishing effluent limits, an application of saltwater and freshwater standards, and allowances to derive site-specific modifications and variances to the standards.

## Point Source Programs

### *PERMITTING PROGRAM*

#### **VPDES Permit Program**

Requirements for chemical specific monitoring are written into Virginia Pollutant Discharge Elimination System (VPDES) permits as special conditions. The Virginia Department of Environmental Quality Toxics Management Program developed these monitoring requirements in the early 1980s. The program aims to involve all

industrial and municipal VPDES permit holders with the potential to discharge chemicals in a systematic program of biological and chemical testing. This testing should identify those wastewater discharges toxic to aquatic life, the specific chemicals responsible for this toxicity, and any chemicals exceeding state criteria or standards.

The need for inclusion of a permittee in the Toxics Management Program is determined at the time of permit issuance, reissuance, or modification using information provided by the permittee as well as additional data from the Department of Environmental Quality or other sources. Generally, the Toxics Management Program special conditions include quarterly chronic and/or acute toxicity testing for one year using both vertebrates and invertebrates. Quarterly chemical testing is required in conjunction with the toxicity testing and includes analyses for all pollutants identified in accordance with section 307(a) of the Clean Water Act (the priority pollutants) as well as for additional organic chemical contaminants detected.

Once the Toxics Management Program data have been generated for a particular outfall, they are evaluated according to several decision criteria specified by the Toxics Management Regulation. These criteria relate to acute and chronic impacts and compliance with water quality standards or criteria. If an effluent demonstrates acute and/or chronic toxicity, the permittee is required to perform a toxicity reduction evaluation, which is described below.

In response to the development and subsequent adoption of the water quality standards for chemicals, the Department of Environmental Quality developed an implementation guidance document for permit writers to determine the appropriate effluent limits for affected plants. Due to conflicts with permittees over draft permits containing toxic limits, the Department of Environmental Quality decided to revise the guidance document. The updated document became available in June 1993 and has resolved

most of the earlier problems. Progress is now being made in drafting chemical-specific permit limits and the staff is working to clear any backlog of pending permits at the state level. Despite the filing of a lawsuit after the Department of Environmental Quality adopted water quality standards for specific chemicals in March 1992, staff continued to draft permits in response to the water quality standards and issued these permits with both acute and chronic limits for whole effluent toxicity.

### **Toxicity Reduction Evaluation**

A toxicity reduction evaluation is a stepwise process for identifying specific chemicals or classes of chemicals responsible for the effluent's toxicity and for evaluating and implementing treatment alternatives to reduce the concentrations to acceptable levels. If chemical data indicate that the effluent either actually or potentially contributes to violations of water quality criteria and/or standards in the receiving stream, water quality-based permit limits for the parameter of concern are recommended for inclusion in the VPDES permit. Appendix A provides a breakdown of current program statistics for VPDES permits in the Bay drainage area.

### **Toxics Management Regulation**

Since November 1988, Virginia's Toxics Management Regulation has driven the Toxics Management Program. Earlier this year, public notification was given that the Virginia Department of Environmental Quality intended to repeal the Toxics Management Regulation to eliminate any confusion and duplication of regulations resulting from the concurrent adoption of a revised VPDES Permit Regulation. The Permit Regulation will include language from the federal NPDES regulations on the evaluation of effluent toxicity and the mechanisms to control toxicity through chemical-specific and whole effluent toxicity limitations. The testing requirements and decision criteria of the Toxics Management Regulation will be used as staff guidance in the implementation of the toxics

control provisions of the VPDES Permit Regulation. Virginia's position on the control of potentially toxic chemicals will not be substantially altered due to these actions.

### **304(l) List**

The 304(l) list refers to a 1987 Clean Water Act section which required the states to develop a list of facilities discharging potentially toxic chemicals (307(a) priority pollutants) in quantities that exceeded state water quality standards or criteria. The 23 plants included in Virginia's 304(l) list that discharge to the Bay drainage area are listed in Appendix A.

Each listed facility was required to develop an Individual Control Strategy to address its discharge of potentially toxic chemicals; all have received approval for their Individual Control Strategies and eight had the provisions of their strategy incorporated into the VPDES permit in the last two years. The 304(l) list plants are being reevaluated as a priority in light of the new water quality standards for specific chemicals. Effluent limits are also being calculated for their permits where necessary.

### ***PRETREATMENT PROGRAM***

The primary purpose of the Pretreatment Program is to protect publicly-owned treatment works (POTWs) and the environment from the adverse impact that may occur when toxic wastes are discharged into a municipal wastewater system. This protection is achieved by regulating the non-domestic users of the POTWs that discharge toxic or unusually strong conventional waste. The POTWs are not usually designed to treat toxic industrial wastes. Such wastes may interfere with the plant's biological treatment processes, pass through untreated into receiving waters, or contaminate sludge to the extent that lawful disposal is severely restricted or precluded. Under the Pretreatment Program, the POTW authorities are responsible for controlling their industrial users.

The Virginia Water Control Board received authorization to administer the Pretreatment Program in April 1989, becoming one of only 25 states having delegated responsibility for all three point source control programs (NPDES Permit, Federal Facilities NPDES Permit, and Pretreatment) authorized under the Clean Water Act.

The 35 POTWs in Virginia's Bay drainage area now have approved pretreatment programs (see Appendix A). These plants receive wastewater from 100 categorical industries subject to federal pretreatment standards due to industrial class and 139 significant non-categorical industries which require inspection at the state level. Since authorization, all POTWs with approved programs have been audited yearly and follow-up actions have been taken to correct any deficiencies. All categorical industries identified in Virginia and nearly 270 significant non-categorical industries have been inspected and the owners advised of the findings. Industrial waste surveys are conducted statewide through special conditions in the VPDES permits and are repeated every five years to determine if other authorities will be required to develop pretreatment programs.

### ***STORM WATER MANAGEMENT PROGRAM***

In 1987, Congress amended the Clean Water Act to include a requirement that EPA develop a phased approach in regulating stormwater discharges under the NPDES permit program. On November 16, 1990, the EPA published the final NPDES Permit Application Regulations for Storm Water Discharges. These regulations established permit application requirements for stormwater discharges from municipal storm sewer systems serving a population of 100,000 or more and for stormwater discharges associated with industrial activity.

There 11 separate municipal storm sewer systems in Virginia's Chesapeake Bay drainage area required to file stormwater permit applica-

tions under the regulations. Of these, three are large municipal systems (with populations greater than 250,000) and the rest are medium-sized municipal systems (with populations between 100,000 and 250,000). Appendix A contains a complete listing of the municipalities required to develop and issue permits under this program. Two additional localities (Richmond and Alexandria) meet the population criteria in the regulation, but their stormwater discharges are being handled under a different program due to the existence of combined sewers.

The localities affected by the regulations must develop stormwater management programs that include two major elements: (1) a program that reduces the discharge of pollutants from municipal storm sewers to the maximum extent practical; and (2) the adoption and implementation of appropriate ordinances to prohibit illicit discharges into stormwater systems (such as illegal hookups or dumping).

The Department of Environmental Quality expects to have a permit issued to each of the affected localities by mid 1994. The permit will require implementation and monitoring of the program. If stormwater monitoring during the permit term (no longer than five years) shows that the management program is not reducing pollution effectively, then the locality must make improvements.

The regulations define the 11 categories of industrial activities required to apply for stormwater permits. The term "industrial activity" covers manufacturing facilities, hazardous waste treatment, storage, or disposal facilities, landfills that receive industrial wastes, recycling facilities, steam electric power generating facilities, transportation facilities, domestic wastewater treatment plants greater than one million gallons per day, and construction activities disturbing five or more acres.

There are an estimated 4,500 industrial facilities and 3,000 to 5,000 construction sites in Virginia

that may file stormwater permit applications under this program. Individual and general permits will be developed and issued for industrial dischargers under this program. An estimated 2,000 additional facilities have also applied for stormwater permits through EPA's "Group Application" process. These facilities will also be issued stormwater permits by the Department of Environmental Quality after EPA develops model permits for each group and forwards these to the states. Stormwater permitting requirements are being incorporated into the VPDES permit program and the permit regulations will be modified to incorporate the stormwater permitting requirements, if necessary.

In June 1993, the State Water Control Board adopted four draft VPDES stormwater general permits as emergency regulations. These regulations allow the Department of Environmental Quality to cover several categories of stormwater discharges (see Appendix A for a complete list of categories). The general permit emergency regulations will expire one year from the effective date. By that time, the Department of Environmental Quality will have taken the four general permits through the administrative process for permanent adoption.

## **Nonpoint Source Programs**

### ***PESTICIDE MANAGEMENT PROGRAM***

The Virginia Pesticide Management Program has undergone significant change since passage of the new Pesticide Control Act in 1989. This legislation created a Pesticide Control Board which has broad powers to carry out enforcement and other mandates of the pesticide act. The Pesticide Control Board has adopted regulations which control pesticide businesses, the certification of pesticide applicators, the establishment of public participation guidelines, and setting of fees. The board is working on regulations for the registration of pesticides and their storage and disposal—both of particular significance to the Chesapeake Bay Program.

Several surveys have been conducted to estimate pesticide use since 1990. Pesticide use information has been gathered for forestry, gypsy moth control, mosquito control, rights-of-way, and ornamental and lawn care pest control as well as agronomic commodities and vegetables (corn, soybeans, tobacco, winter wheat, small grains, tomatoes, and potatoes) in Virginia.

In 1990, Virginia initiated a program to collect and dispose of unwanted pesticides from agricultural producers. This highly successful program has safely and properly removed and destroyed more than 87 tons of pesticides which posed a potential threat to health and the environment. A pilot program to recycle plastic pesticide containers properly has also been implemented.

The Virginia Pesticide Control Board has also funded research for the past three years. Major areas of supported research have focused on alternatives to traditional chemical pesticides and determination of the extent of pesticide contamination in groundwater. This research should lead to reduced pesticide use and wider application of integrated pest management practices. Data from the groundwater studies will add important new information to the understanding of Virginia's hydrogeology and the impact of pesticide use on Virginia's groundwater resources. A task force completed the drafting of the Generic Pesticides and Ground Water Management Plan for Virginia, in May, 1993. Now under review by the EPA, this plan will guide future pesticide-specific management plans should they be required and the establishment of procedures for protecting human health and the environment.

## **Hazardous Waste Management Programs**

The Waste Division of the Department of Environmental Quality is responsible for the regulatory programs addressing solid waste, hazardous waste and hazardous materials, and the state Superfund Program. These programs en-



compass management of solid, hazardous, and radioactive waste, emergency planning for hazardous materials (SARA Title III), and hazardous materials transportation activities. Recent emphasis has been on identifying waste reduction approaches.

The Waste Division has jurisdiction over four areas of activity which present a potential threat to public health and the environment. Threats exist from: (1) chemicals used in production processes; (2) the subsequent generation, treatment, storage, and disposal of hazardous materials, both products and wastes; (3) the transportation of hazardous materials; and (4) the management of solid (non-hazardous) wastes which include household hazardous and industrial wastes.

### ***SOLID WASTE MANAGEMENT PROGRAM***

“Solid waste” consists of non-hazardous waste such as garbage, debris, dewatered sludge, scrap metal, white goods, and other disposed of or abandoned materials. The Waste Division regulates solid waste management facilities, including sanitary, construction/demolition/debris, and industrial landfills; materials recovery facilities; energy recovery and incineration facilities; composting facilities; and solid waste transfer stations.

A significant area of concern is the storage and final disposal of generated waste. Waste disposed of in landfills represents a potential long-term liability although regulations for solid waste management programs are now integrating new design standards for land disposal facilities. Older solid waste facilities that do not meet new standards are being phased out of operation by federal mandates. The Waste Management Division administers three solid waste programs which directly support the toxics reduction strategy: solid waste management program, waste management planning, and litter control and recycling.

### ***RCRA PROGRAM***

Commercial and industrial facilities which generate, store, treat, dispose of, or transport hazardous wastes are subject to RCRA. Virginia has adopted Hazardous Waste Management Regulations which integrate RCRA’s requirements for handling waste from “cradle to grave.” Although it is difficult to estimate the amount of hazardous waste produced in Virginia, changes in the regulations in 1990 caused previously unregulated wastes to fall within the domain of RCRA, widening the sphere of regulated wastes. Virginia does not currently have a permitted commercial and chemically secure landfill facility for the disposal of hazardous waste.

The Waste Division administers five hazardous waste or hazardous materials programs that support a basinwide toxics reduction strategy: a hazardous waste management program; state site certification for hazardous waste management; Virginia Hazardous Waste Capacity Assurance Program; Virginia Emergency Response Council (SARA Title III); and an environmental response and remediation program.

### ***SUPERFUND PROGRAM***

The Waste Division also administers a related program, Superfund, in support of the basinwide strategy. Superfund includes state participation in the investigation and clean up of existing or abandoned sites where serious threats to human health or the environment exist due to past disposal practices or continued releases from non-permitted facilities.

## ***Air Quality Control Program***

The Air Toxics Program in the Department of Environmental Quality is charged with the maintenance and improvement of the state’s air quality. Emphasis is now being directed at a health-based state air toxic pollution control program and the technology-based hazardous air pollution control

program requirements of the 1990 Clean Air Act Amendments.

In 1989, following a four-year pilot program, the department began a statewide evaluation of toxic chemical emissions from existing facilities, while reviewing new and modified permit applications for toxic chemical emissions under the state program. Between 1988 and 1990, approximately 300 facilities were inventoried statewide (including facilities near the Chesapeake Bay). This inventory resulted in the identification of chemicals emitted at significant levels, leading to the development of some permit limits and testing requirements. With the passage of the 1990 Clean Air Act Amendments, the inventory process was curtailed because the federal operating permit requirements of the act would accomplish the same purpose as the state inventory.

Currently, the state air toxics program is an established part of the department's facility review procedure. The department's air toxics regulations address 238 toxic chemicals. The development of an air toxics data base has been delayed but is being revived under requirements of the 1990 Clean Air Act Amendments.

Since the signing of the 1989 Basinwide Toxics Reduction Strategy, the department has: 1) provided emission inventory data to Chesapeake Bay Program contractors; 2) conducted one year (1990) of toxics canister sampling of 41 volatile organic chemicals in the Tidewater (Hampton) area; and 3) conducted two years (1989 to 1990) of non-methane organic compound canister sampling in Norfolk and one year (1990) of non-methane organic compound canister sampling in Chesapeake. Due to a reduction in

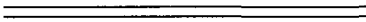
department resources, the only canister sampling currently being performed is in Hopewell.

### Atmospheric Deposition

Other monitoring activities being conducted near the Bay include: 1) acid precipitation monitoring (Hampton, West Point) for pH, ammonium, fluoride, chloride, bromide, nitrate, sulfate, and phosphate; and 2) the Chesapeake Bay Atmospheric Deposition Study (Haven Beach, Mathews County). Researchers from the Virginia Institute of Marine Sciences and Old Dominion University are measuring metals and organic contaminants in atmospheric deposition at Haven Beach, Virginia.

The requirements of the 1990 Clean Air Act Amendments necessitate a toxic chemical emissions inventory of all applicable facilities in Virginia. The initial survey of these sources began in the late summer of 1993. This information will be updated annually, providing a much more extensive and accurate inventory of emissions to evaluate. This information should be available to interested parties by mid-1994.

The Air Division will assist in providing any information pertinent to the Great Waters Program—the 1990 Clean Air Act Amendments (Section 112(m)) study which includes Chesapeake Bay. This study will use emissions inventory data to assess the relative atmospheric loading of toxic pollutants into the Bay. Updates of the toxic chemical emission inventory should assist with periodic assessments and provide input for more refined atmospheric dispersion models of the Bay.



# PROGRESS TOWARDS THE STRATEGY'S GOALS

## Interim and Long-Term Goals

Since the Toxics Subcommittee was established in September 1989, it has focused on defining key Bay toxics problems and issues and implementing the Basinwide Toxics Reduction Strategy. The Toxics Subcommittee increasingly emphasized linking strategy implementation and budget priorities with progress in achieving the two goals of the strategy:

"The long-term goal of this Strategy is to work towards a toxics free Bay by eliminating the discharge of toxic substances from all controllable sources."

"By the year 2000, the input of toxic substances from all controllable sources to the Chesapeake Bay will be reduced to levels that result in no toxic or bioaccumulative impacts on the living resources that inhabit the Bay or on human health."

The basinwide strategy contained the commitment that "by December 1989, the signatories commit to completing the design of a system for measuring progress under the Basinwide Toxics Reduction Strategy" [53]. The Toxics Subcommittee identified a set of measures against which "results" from strategy implementation are com-

pared to gauge progress. A set of milestones was established to lay the groundwork for a system to measure progress towards achievement of the strategy's two goals (Table 49) [42].

## Implementation Progress

To provide a sense of the diversity of efforts undertaken to control, reduce, and prevent loadings and releases of potentially toxic chemicals into the Bay basin and progress being made towards the basinwide strategy goals and commitments, a series of brief implementation "stories" are summarized below. These stories have been selected to provide particular examples of both programmatic and environmental progress as well as areas requiring attention in the future.

## Definition of Bay Toxics Problems

Significant progress has been made in better defining the nature, extent, and magnitude of the Bay's toxics problems. Because of our increased confidence in understanding toxics problems, managers are able to act on a prioritized set of reduction and prevention activities, while focusing on a more narrowed set of monitoring, assessment, and research needs.

### *Box 9. Selected Chesapeake Bay toxics data and literature synthesis books, reports, and papers*

*Atmospheric Deposition of Nitrogen and Contaminants to Chesapeake Bay and its Watershed [304]*  
*Chesapeake Bay: A Technical Synthesis [292]*  
*Contaminants in Chesapeake Bay: The Regional Perspective [150]*  
*Contaminant Problems and Management of Living Chesapeake Bay Resources [182]*  
*Low-Level Effect of Toxic Chemicals on Chesapeake Bay Organisms [338]*  
*Occurrence and Distribution of Pesticides in Chesapeake Bay [163]*  
*Sources, Cycling, and Fate of Contaminants in Chesapeake Bay [259]*  
*The Chesapeake Bay Toxics Issue Revisited [337]*

**Table 49.** Milestones for measuring progress towards the interim Basinwide Toxics Reduction Strategy goal.

<b>Milestone 1:</b>	Definition of the magnitude and extent of regional and baywide toxics problems and their relative risk to the Chesapeake Bay system and implementation of actions to address the identified toxic problems.
<b>Milestone 2:</b>	Achievement of the Basinwide Toxics Reduction Strategy commitments.
<b>Milestone 3:</b>	Reduction of toxic substance loadings below the baseline loadings established through the Basinwide Toxics Loading and Release Inventory to ambient concentrations which meet EPA water quality criteria and state water quality standards and cause no toxic impact.
<b>Milestone 4:</b>	Elimination of the discharge of waste water that causes an acute or chronic impact, initially from point sources which discharge below the fall line and then from point sources which discharge above the fall line.
<b>Milestone 5:</b>	Reduce ambient concentrations of toxic substances within the waters and sediments of Chesapeake Bay to concentrations that have no toxic impact on Bay living resources.
<b>Milestone 6:</b>	Manage the application of pesticides to lower ambient levels of pesticides to concentrations at which there is no toxic impact to living resources within the waters and sediments of Chesapeake Bay.
<b>Milestone 7:</b>	Minimize loadings of toxics substances into the waters of Chesapeake Bay through implementation of pollution prevention activities addressing industrial processes, agricultural practices, homeowner activities, and stormwater controls.

Source: Chesapeake Bay Program 1991c.

### **BAY BASIN STATES 304(L) LISTS**

Under the 1987 amendments to the Clean Water Act, the states were required to list those that discharge potentially toxic chemicals in quantities exceeding water quality standards or criteria. Sixty-eight facilities were identified within the Chesapeake Bay basin (Figure 34; Appendix B). To address their discharges, each facility was required to develop an individual control strategy—an NPDES permit containing conditions necessary to meet applicable water quality standards for the identified chemicals.

### **ELIZABETH RIVER INITIATIVE**

The Hampton Roads Harbor, a major deep water port, is situated on the Elizabeth River, a sub-estuary of the James River. The Elizabeth River watershed drains over 300 square miles and is among the most heavily urbanized and industrialized areas in the state. Low topographic relief and poor flushing has resulted in a river that

functions more like a lake than a free-flowing estuary.

In 1983, the Chesapeake Bay Program identified the Elizabeth River system as one of the most heavily polluted bodies of water in the Bay watershed. In response to ongoing as well as historical studies which indicated elevated concentrations of polynuclear aromatic hydrocarbons and metals in the river, a comprehensive Elizabeth River Restoration Strategy was implemented in 1988. The following Elizabeth River Toxics Initiative activities from 1989 through 1992 illustrate management efforts to assess and implement control strategies for restoration of the Elizabeth River.

- A total of 182 sets of effluent samples were collected for chemical analysis of priority and non-priority metals and organic chemicals from 95 outfalls at 40 facilities throughout the tidewater region.

### Chesapeake Bay Basin 304(l) Facilities



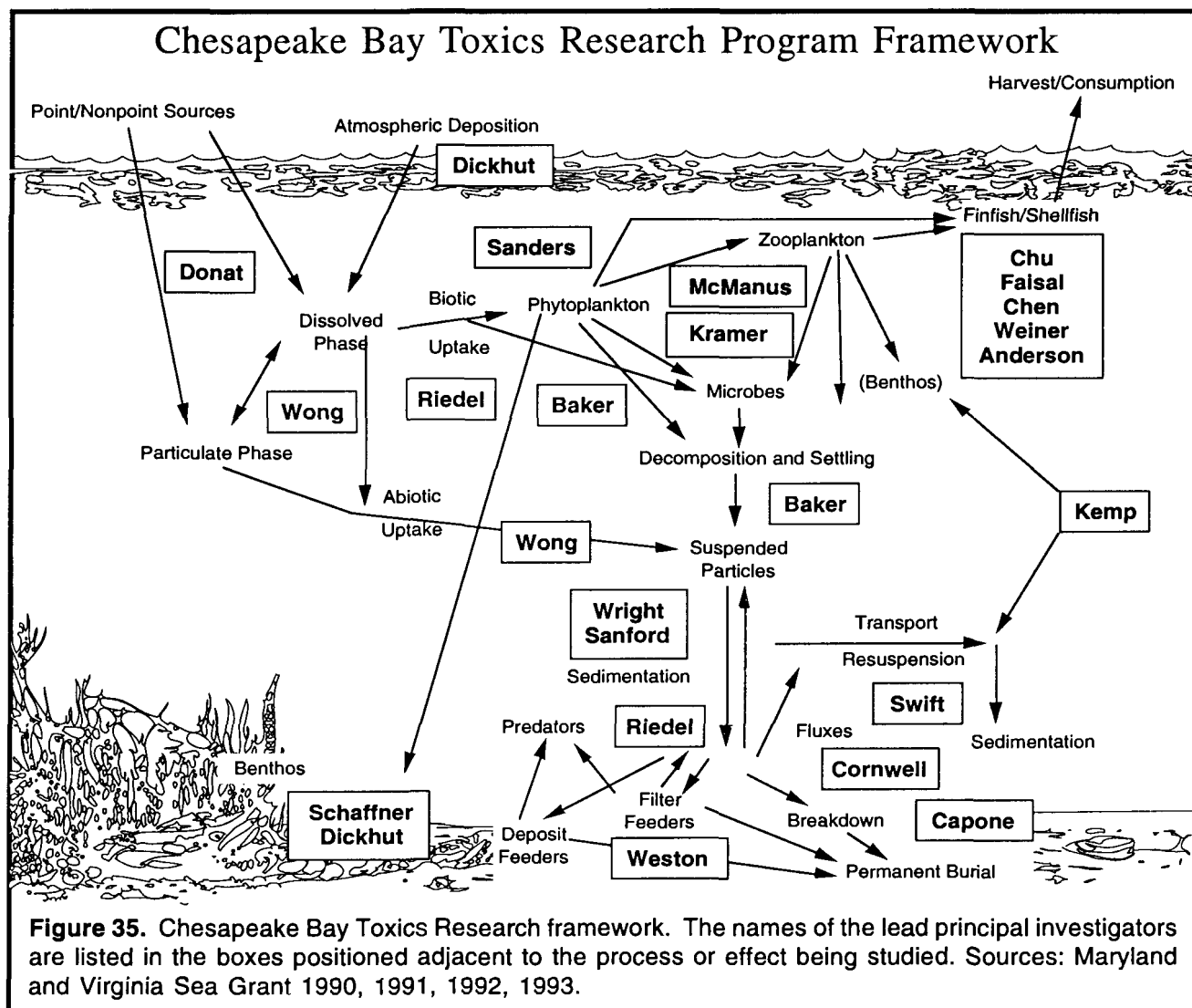
**Figure 34.** Locations of the state designated 304(l) facilities (●) within the Chesapeake Bay basin.  
Source: U.S. EPA Region 3, unpublished data.

## Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

- Sixty-six static acute tests using marine test species were conducted from October 1988 to October 1990. The Virginia State Water Control Board staff use this information during modification or reissuance of VPDES permits.
- Two regional permit writers and one inspector, dedicated to the facilities on the Elizabeth River, have provided the necessary regulatory focus in protecting water quality. Inspections have more than doubled since the inspector was hired.
- A best management practice was developed for shipyard management and to ensure consistency in conducting inspections at the 24 shipyards along the Elizabeth River.
- A project designed to study oily waste treatment technologies revealed that in some cases the treatment units operated with negative removal efficiencies. Oil and grease use, as a measured parameter, does not correlate well with toxicity.
- A frequency distribution model was developed for the Elizabeth River which includes a list of 251 extractable organic chemicals. This information will be used for toxicity assessments and for prioritizing water quality standards development and adoption.

### Box 10. Chesapeake Bay Program Reports directly sponsored by the Toxics Subcommittee

*A Pilot Study for Ambient Toxicity Testing in Chesapeake Bay - Year One Report* [114]  
*A Pilot Study for Ambient Toxicity Testing in Chesapeake Bay - Year Two Report* [113]  
*A Pilot Study for Ambient Toxicity Testing in Chesapeake Bay - Year Three Report* [110]  
*A Review of Estuarine Aquatic Toxicity Data for the Development of Aquatic Life Criteria for Atrazine in Chesapeake Bay* [121]  
*An Updated Review of Estuarine Aquatic Toxicity Data for the Development of Aquatic Life Criteria for Atrazine in Chesapeake Bay* [122]  
*An Assessment of Salinity Effects on the Toxicity of Atrazine to Chesapeake Bay Species: Data Needs for Annual Loading Estimates of Urban Toxic Pollutants in the Chesapeake Bay Basin* [224]  
*Chesapeake Bay Ambient Toxicity Assessments Workshop* [170]  
*Chesapeake Bay Atmospheric Deposition Study. Phase I: July 1990-June 1991* [11]  
*Chesapeake Bay Atmospheric Deposition Study. Phase II: July 1990-December 1991* [14]  
*Chesapeake Bay Atmospheric Deposition of Toxics Critical Issue Forum Proceedings* [45]  
*Chesapeake Bay Basinwide Survey of Toxic Analytical Capabilities Survey and Assessment* [137]  
*Chesapeake Bay Basin Toxics Loading and Release Inventory* [50]  
*Chesapeake Bay Basin Toxics Loading and Release Inventory: Technical Update - Point Sources by Facility* [51]  
*Chesapeake Bay Contaminated Sediment Critical Issue Forum Proceedings* [48]  
*Chesapeake Bay Fall line Toxics Monitoring Program: 1990-1991 Loadings* [193]  
*Chesapeake Bay Fall line Toxics Monitoring Program: 1992 Interim Report* [194]  
*Chesapeake Bay Fall line Toxics Monitoring Program: 1992-1993 Loading Report* [195]  
*Chesapeake Bay Finfish/Shellfish Tissue Contamination Critical Issue Forum Proceedings* [46]  
*Chesapeake Bay Groundwater Toxics Loading Workshop Proceedings* [47]  
*Chesapeake Bay Toxics of Concern List* [40]  
*Chesapeake Bay Toxics of Concern List Information Sheets* [41]  
*Chesapeake Bay Water Column Contaminant Concentrations Critical Issue Forum Proceedings* [49]  
*Comprehensive List of Chesapeake Bay Basin Toxic Substances* [43]  
*Contaminants in Chesapeake Bay Sediments: 1984-1991* [76]  
*Development of a Chronic Sediment Toxicity Test for Marine Benthic Amphipods* [68]  
*Development of Estuarine Criteria* [108]  
*Pilot Monitoring for 14 Pesticides in Maryland Surface Waters* [169]  
*Screening of Candidate Species for Development of Standard Operating Procedures for Aquatic Toxicity*  
*Southern Chesapeake Bay Atmospheric Deposition Study, Year 1 Report* [70]  
*Standard Operating Procedures for Conducting Acute and Chronic Aquatic Toxicity Tests with *Eurytemora affinis*, a Calanoid Copepod* [343]  
*Status and Assessment of Chesapeake Bay Wildlife Contamination* [48]  
*The Influence of Salinity on the Chronic Toxicity of Atrazine to an Estuarine Copepod: Filling a Data Need for Development of an Estuarine Chronic Criterion* [109]  
*Testing with Resident Chesapeake Bay Biota* [342]



## Achievement of Strategy Commitments

A large majority of the 80 commitments in the basinwide strategy have been completed or are underway. Appendix C provides a summary matrix of the strategy commitments and current status. Progress towards several commitments dealing with existing regulatory and statutory requirements has not been effectively tracked through the existing system.

### INTEGRATED BAY TOXICS RESEARCH PROGRAM

In 1990, a Chesapeake Bay Toxics Research Program was established through joint funding by the Chesapeake Bay Program and the National Oceanic and Atmospheric Administration. The

research program has two goals: to understand how Chesapeake Bay ecosystem processes influence the transport, fate, and effects of potentially toxic chemicals; and to understand the effects that representative chemicals have upon ecological processes, including trophic dynamics, in the Bay. These goals are being accomplished through the development of a unique, interdisciplinary, and inter-institutional research program, administered jointly by the Maryland and Virginia Sea Grant programs. The research program is focusing on the effect that low levels of potentially toxic chemicals have on living resources in areas other than those with known toxics problems (Figure 35). Major findings from the first three years of the program are described on pages 47-50.

## LOADING AND RELEASE INVENTORY

The Chesapeake Bay Basinwide Toxics Loading and Release Inventory is the first step in the establishment of a comprehensive baseline of loadings and releases. As baselines are established for the different sources of potentially toxic chemicals, more detailed accounts of progress in loading reductions can be tracked and reported within and across the jurisdictions.

## Reductions in Chemical Loadings

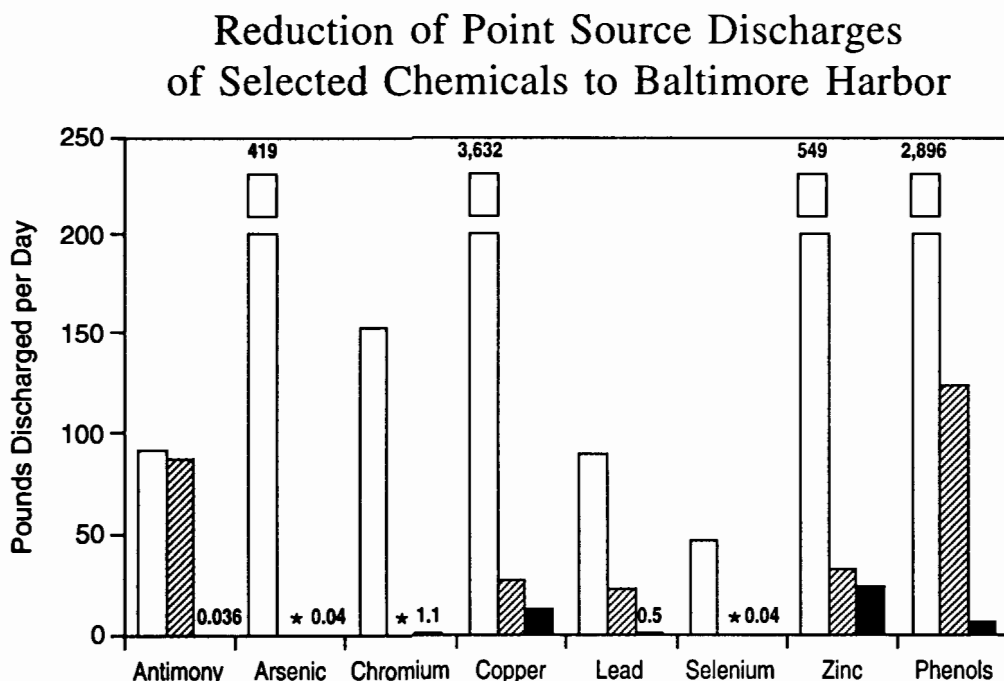
### BALTIMORE HARBOR BOTTOM HABITAT RESPONSES

Maryland Department of the Environment's Industrial Discharge Program has documented substantial reductions in toxic chemicals and conventional pollutants discharged into Baltimore Harbor and the Patapsco River since the implementation of Maryland's NPDES Program

in 1974 (Figure 36). For example, chromium, lead, zinc, and copper from some of the most significant point source discharges to Baltimore Harbor were reduced by 99, 75, 94, and 99 percent, respectively, from 1975 to 1988. These reductions are attributed to both the NPDES program and the closing of a major metal industry. During this period of documented declines, biological assessments of Baltimore Harbor and the mouth of the Patapsco River indicated substantial improvements in the benthic community's species abundance and diversity.

### INDUSTRIAL PROGRESS STORY - NORSHIPCO

NORSHIPCO, a shipbuilding and repair facility on the Elizabeth River, had a toxic discharge of oily wastewater. The only treatment this contaminated waste water received was use of an oil/water separator. Sampling conducted as a requirement under the Toxics Management Program indicated an extremely toxic effluent. As a result, a Toxics Reduction Evaluation was ini-



**Figure 36.** Reductions in point source discharges of selected metals and phenol to Baltimore Harbor from selected NPDES permitted facilities. \* = No data, = <1975, = 1988, = 1992. Source: Maryland Department of the Environment, unpublished data (c).



tiated in 1988. The shipyard decided to provide pretreatment and send the oily waste water to the local sewage authority in 1993.

### **INDUSTRIAL PROGRESS STORY - WAYNETEX**

Waynetex, a manufacturer of a woven polypropylene and polyethylene fabric, formerly discharged effluent into the Potomac River. The Virginia Toxics Management Program found the discharge to be acutely toxic due to a surfactant present at toxic concentrations in the cooling water. The manufacturer implemented in-house pollution prevention measures by controlling the potential overflow of surfactant into the cooling water and sending the waste water to the local municipal wastewater treatment plant.

### **LEAD CONCENTRATION DECLINES IN PRECIPITATION**

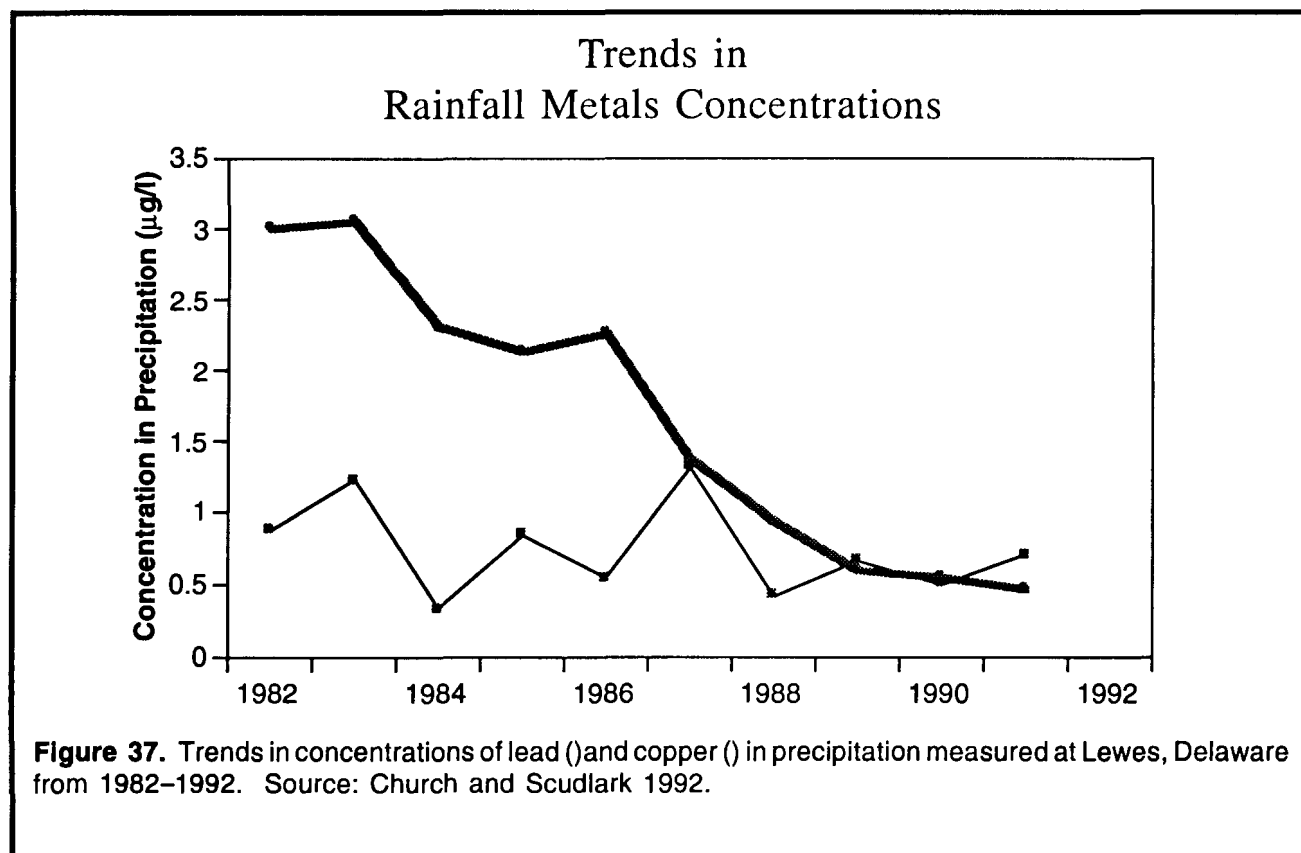
Scientists from the University of Delaware have observed significant declines in the lead

concentrations of precipitation at the Lewes, Delaware atmospheric deposition monitoring station since 1982 (Figure 37). This decline is the result of banning lead as a gasoline additive. Over the same period, there have been no declining trends in the concentrations of other metals (e.g., copper).

### **VIRGINIA PESTICIDE MIXING AND LOADING FACILITIES**

Pesticide mixing and loading facilities may be a significant source of pesticide loadings to local and regional environments from the routine operation of these facilities. The Virginia Department of Conservation and Recreation's Division of Soil and Water Conservation became aware of this potential loading source through a program to monitor water quality improvements resulting from the implementation of best management practices.

Samples collected at the main sampling station, located approximately one-quarter mile



downstream of a fertilizer and chemical mixing and loading facility, showed consistently high concentrations of atrazine and metolachlor after moderate to intense rainfall (Figure 38). Direct sampling of the facility's stormwater outfall showed concentrations as high as 9,006 ug/L of metolachlor and 2,858 ug/L of atrazine. In co-operation with the Southern States Cooperative facility, best management practices were installed with changes in operation procedures in the fall of 1988. As a result of these structural and procedural changes, pesticide concentrations downstream of the facility declined dramatically.

The Chesapeake Bay Program has supported a statewide inventory of agricultural chemical mixing and loading facilities. The purpose of this inventory, scheduled to be conducted in the spring of 1994, is to assess the potential impact of these facilities on water quality.

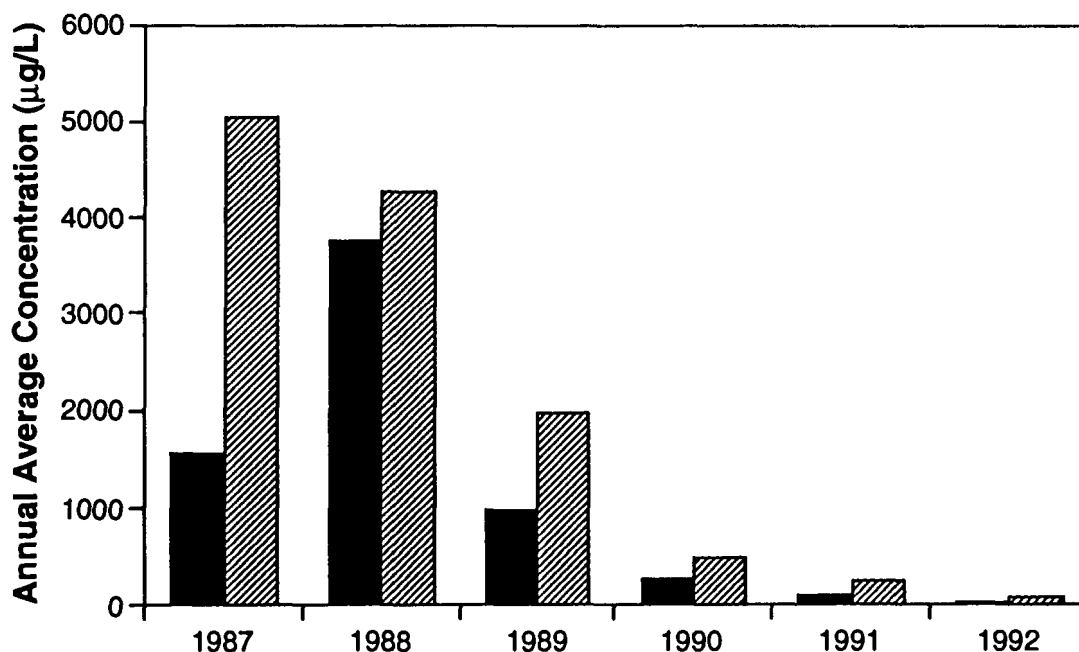
## Elimination of Acutely or Chronically Toxic Discharges

### *VIRGINIA'S TOXICS MANAGEMENT PROGRAM*

In its portion of the Chesapeake Bay drainage area, Virginia currently has 269 industrial and municipal dischargers in the Toxics Management Program. The program requires each discharger to monitor its effluent using acute and chronic toxicity tests if applicable and monitor for priority and non-priority pollutants. The biological data are evaluated to determine if the decision criteria of the Toxics Management Regulation have been met, the chemical data are compared to water quality standards to find possible in-stream violations.

Currently, 53 facilities in the Bay basin have failed the decision criteria of the regulation and

**Pesticide Concentrations Downstream  
of a Virginia Pesticide Mixing and Loading Facility**



**Figure 38.** Annual average concentrations of the pesticides atrazine (■) and metolachlor (▨) recorded at a sampling station a one-quarter mile below the Southern States Prince William-Facquier Cooperative Inc.-Calverton Branch pesticide mixing and loading facility. Best management practices were installed and changes in facility operations were initiated in 1989. Source: Virginia Department of Conservation and Recreation, unpublished data.

are required to conduct a toxicity reduction evaluation. Eight facilities have completed their evaluations while several others are very close to achieving the goal of toxicity reduction or elimination. Following completion of the toxicity reduction evaluation, whole effluent toxicity limitations are applied when toxicity is exhibited in the whole effluent tests. Chemical-specific limitations are included when water quality violations occurred.

## Reduce Ambient Concentrations of Chemicals

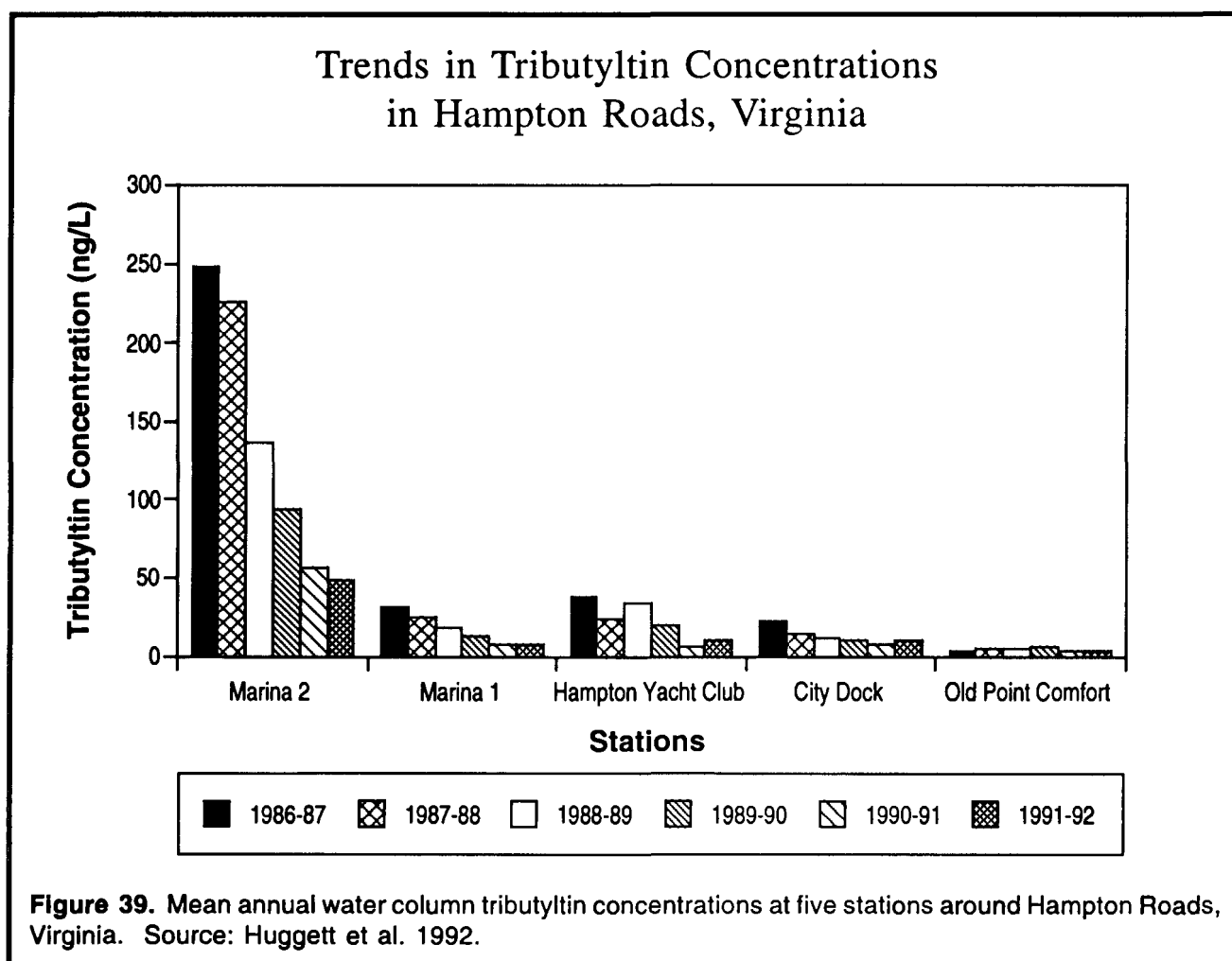
### *DECLINES IN WATER COLUMN TRIBUTYLTIN CONCENTRATIONS*

Scientists at the Virginia Institute of Marine Science have documented significant declines in water column concentrations of tributyltin, a

chemical used as an additive to boat bottom antifouling paint. Declining concentrations over a seven-year period occurred at sites in and around a heavily industrialized harbor surrounded by naval, commercial, and recreational shipyards and marinas (Figure 39). Similar declines occurred within a strictly recreational marina (Figure 40). Tributyltin concentrations began to decline in 1987, the same year that the states of Maryland and Virginia enacted restrictions on the use tributyltin in boat bottom paints. Tributyltin products are now classified as "restricted use" and can only be applied by certified applicators at licensed marinas.

### *RECENT DECLINES IN SEDIMENT CONTAMINANT CONCENTRATIONS*

Using sediment core analyses, scientists at the University of Maryland have recorded peaks



in sediment concentrations of metals in the late 1940s and in the 1970s for polycyclic aromatic hydrocarbons with significant declines through the early 1990s. Currently, sediment metal concentrations are at levels similar to those of the 1920s (Figure 19). Current polycyclic aromatic hydrocarbon sediment concentrations are at concentrations found in middle mainstem Bay sediments during the late 1800s (Figure 21).

### MARYLAND SHELLFISH TISSUE CONTAMINANT TRENDS

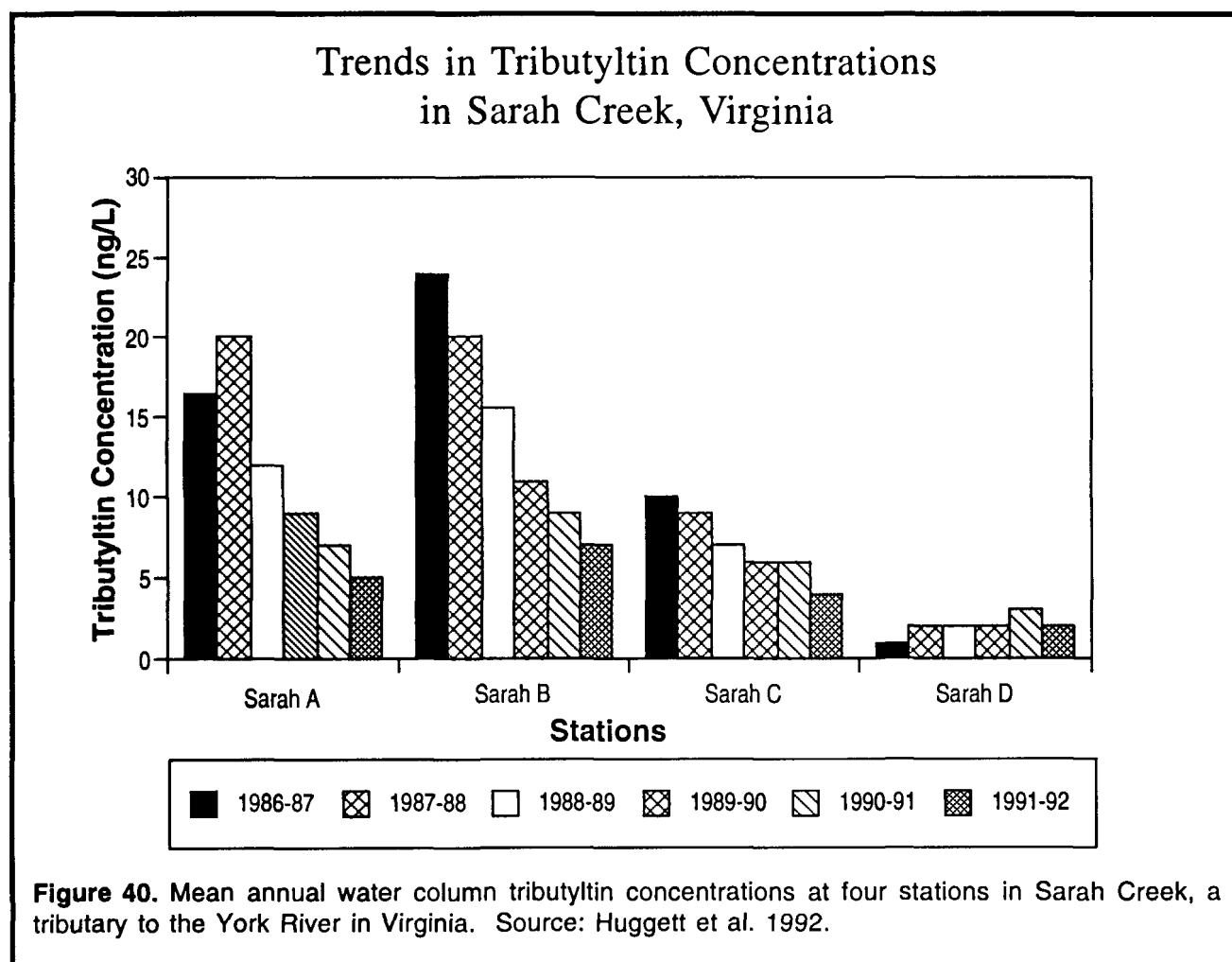
Maryland's Shellfish Monitoring Program has documented declines in shellfish tissue concentrations of arsenic, cadmium, copper, mercury, and zinc from 1974 to 1990 (Figures 27-31). The magnitude of concentration reductions for the five metals ranged from 50 to 90 percent. For the first year since the monitoring began in the early

1970s, the 1990 data for oyster tissue data also recorded no detection of the insecticide chlordane which was banned in 1987.

### KEPONE IN THE JAMES RIVER

From 1966 through 1975, an estimated 199,580 pounds of kepone, a persistent chlorinated hydrocarbon insecticide, was released to the James River and surrounding environment through atmospheric emissions, wastewater discharge, and disposal of off-specification batches during production of this pesticide. Kepone contamination in the tidal James River extended from Hopewell to Newport News, Virginia; scientists found fish adulterated with the substance as far upriver as Richmond, Virginia.

In July 1975, the Virginia Department of Health closed Life Sciences Products Inc. be-



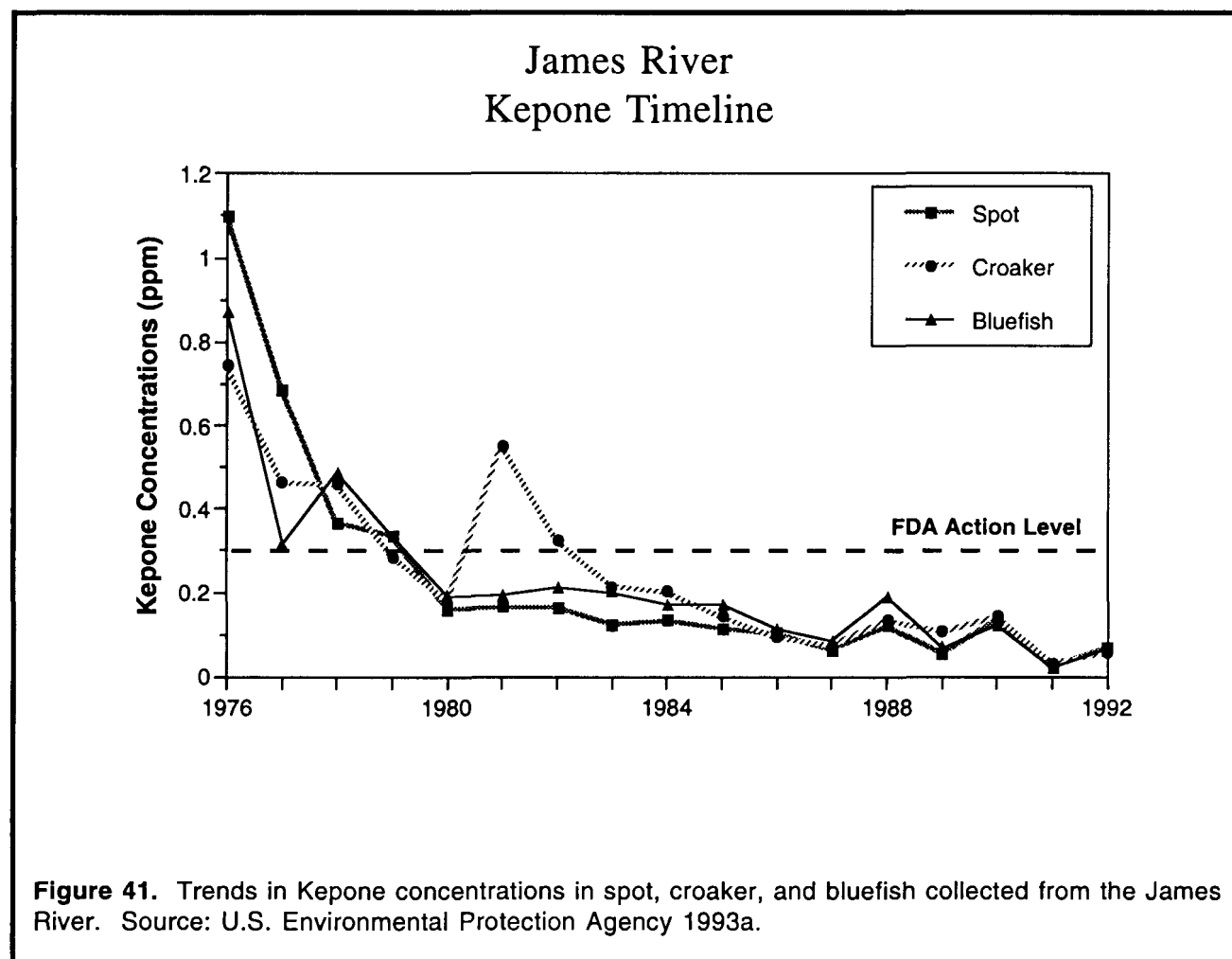
cause of inadequate employee protection in kepone production. State and federal government staff evaluated the situation and initiated research and monitoring efforts to determine the extent and degree of the kepone problem. They found widespread kepone contamination of water, sediment, finfish, and shellfish and closed the James River to all finfish and shellfish harvesting. After a thorough review, the state permitted catches of shad, herring, catfish, and female blue crabs. The fishing ban was further modified over the years as scientists gathered additional monitoring information. In 1980, the sportfishing ban was lifted and by 1981 commercial fishing resumed for shellfish and all finfish except striped bass.

The water, sediment, and finfish of the tidal James River are still contaminated with kepone. Fortunately, kepone concentrations in all areas have decreased and should slowly continue to

drop over the years due to the burial and dilution of kepone-containing sediments by less contaminated sediments (Figure 41). Monitoring of kepone concentrations in the sediment and fish will continue throughout the contaminated reach of the James River, providing assurance that consumers of Virginia's seafood remain protected.

### ***BASINWIDE DECREASES IN WILDLIFE CONTAMINATION***

Dramatic decreases in the concentrations of chemical contaminants in birds over the past 20 to 30 years have resulted in increasing numbers of bald eagles and ospreys, the two species most impacted (Figure 42). Levels of chlorinated pesticides were once at sufficiently high concentrations to cause eggshell thinning and mortality in these two species. By the late 1970s and early 1980s, concentrations of these contaminants had



dropped to levels that no longer impacted the Bay's raptor populations (Tables 46 and 47).

## Manage the Application of Pesticides

Jurisdictional efforts to implement pesticide management programs within the Bay basin have progressed significantly and are highlighted below. Ultimately, progress must be measured as reductions in ambient concentrations of pesticides to levels below which there is no potential for adverse effects on the Bay's living resources.

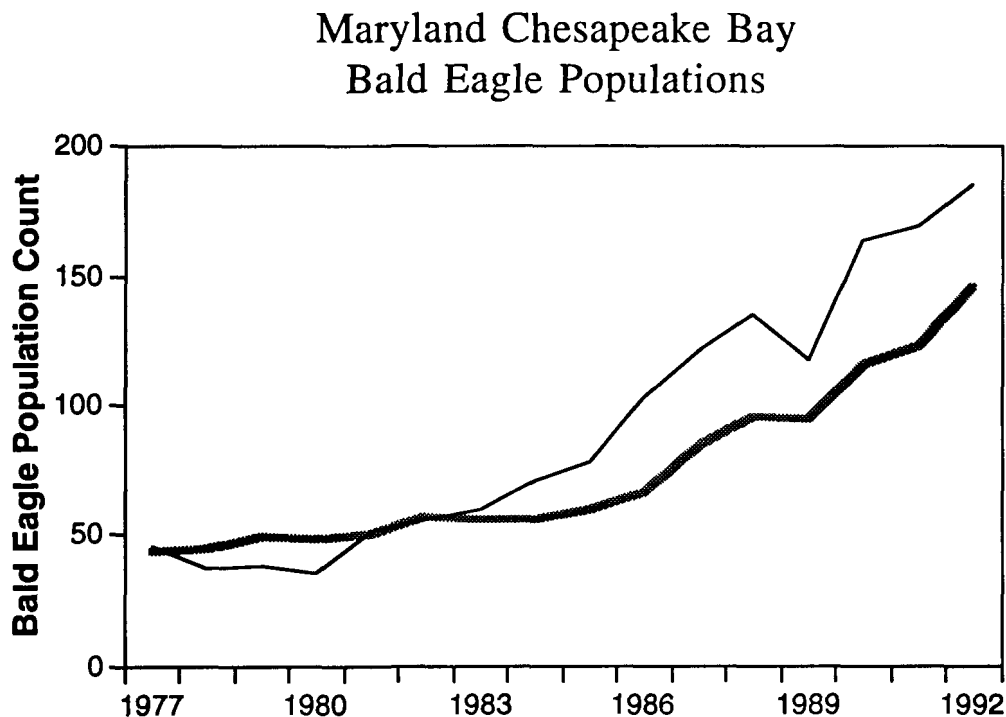
### ***BASINWIDE INCREASES IN INTEGRATED PEST MANAGEMENT IMPLEMENTATION***

Pennsylvania, Maryland, and Virginia have made substantial progress in bringing hundreds

of thousands of acres of the bay watershed under a system of integrated pest management (Figure 43). Integrated pest management practices are also used on thousands more acres that are outside of the formal Cooperative Extensive Service programs in these three Bay basin jurisdictions.

### ***PENNSYLVANIA'S ONE-PLAN PROGRAM***

The "one plan" concept is an attempt by state and federal agencies administering programs for farmers to integrate these programs. The result will be a single integrated plan for each farm that meets all state and federal requirements. Programs such as integrated pest management and nutrient management will be coordinated at the farm level to assure that conflicts between different management practices do not develop. A pilot program in Pennsylvania's York County is field



**Figure 42.** Bald eagle active nests (O) and young (O) counts in the Maryland portion of Chesapeake Bay from 1977 through 1992. Source: U.S. Environmental Protection Agency 1993a.

testing the development of a single plan to assist farmers with the compliance of three Pennsylvania laws (Pennsylvania Clean Streams, Pennsylvania Nutrient Management Law, and Pennsylvania Dam Safety and Encroachment Act) and three federal acts (1985 Food Security Act, 1990 Food, Agriculture, Conservation, and Trade Act, and the Federal Insecticide, Fungicide, and Rodenticide Act).

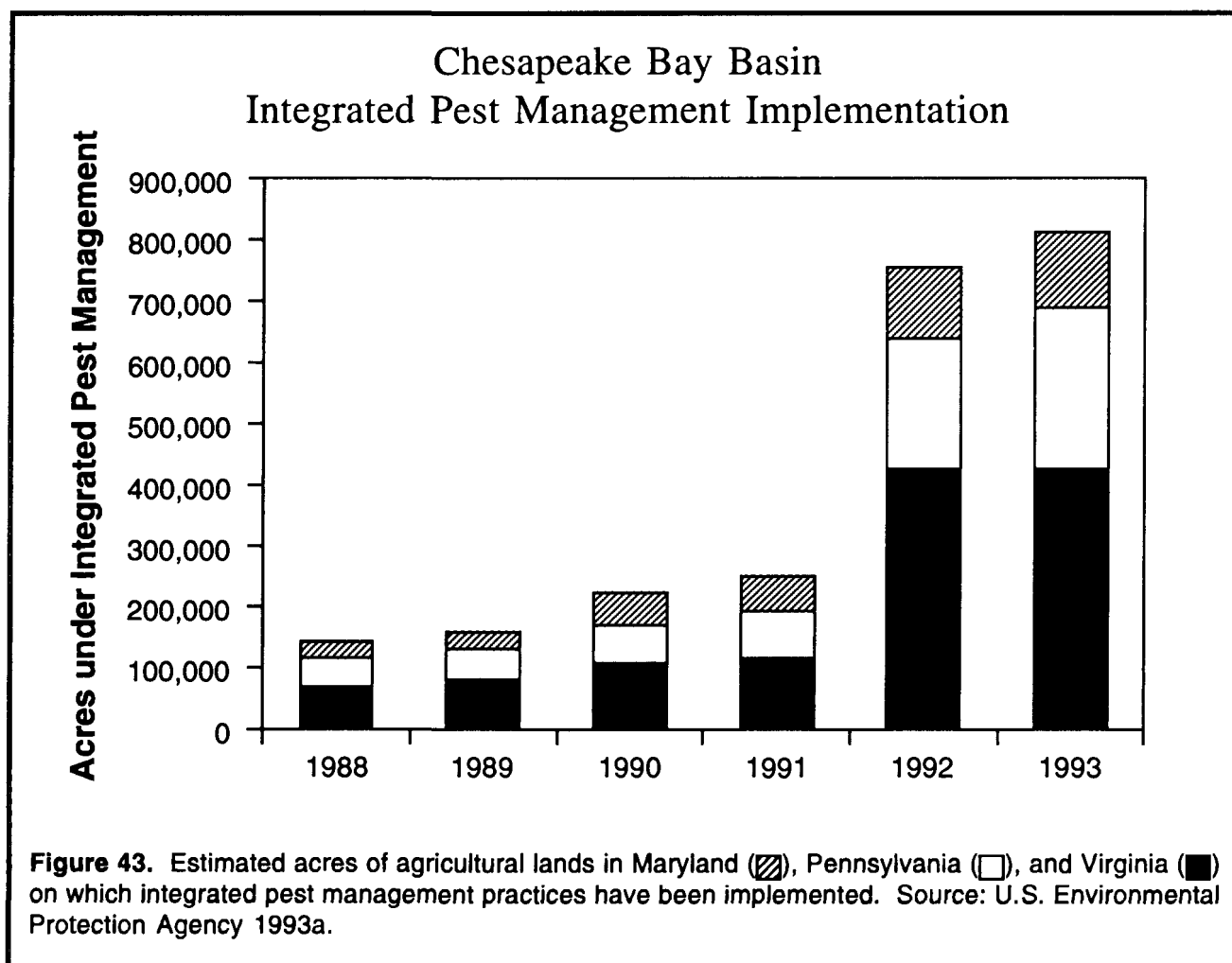
### **IMPLEMENTATION OF ATRAZINE BEST MANAGEMENT PRACTICES**

The Maryland Department of Agriculture has developed and implemented a best management practices program to reduce the possibility of atrazine, a herbicide, from reaching drinking water supplies and to reduce runoff to surface waters. Atrazine is the most widely used pesticide in the Chesapeake Bay watershed. Due to its wide-

spread use and persistence in the environment, it has been listed as a Chesapeake Bay Toxic of Concern.

Recommended best management practices for atrazine include: proper handling, storage, and disposal; use of cultural and tillage practices; maintenance of a 50-foot setback from wells when mixing, loading, or using atrazine; implementation of a 200-foot application buffer around lakes, reservoirs, and public water supplies; maintenance of a 66-foot application buffer from points where surface water runoff from fields enters streams and rivers; and delayed use of atrazine if heavy rains are forecast.

The program for growers and commercial pesticide applicators recommends landowner evaluation of each farm site to determine if best management practices are in place or are needed



to protect ground and surface water when using, storing, and disposing of atrazine products. While these best management practices focus on atrazine, they are equally effective for other pesticides.

Education materials, including a best management practices brochure, farm site evaluation, training video, manual on the use of the best management practices, and best management practices posters have been developed for distribution to farmers, pesticide applicators, and dealers. Training sessions addressing the purpose and implementation of the best management practices have been conducted for the agricultural community on a statewide basis in Maryland. An atrazine best management practices display was developed and shown at several agricultural conventions, training sessions, and seminars.

#### ***ATRAZINE ESTUARINE CRITERIA DEVELOPMENT***

In 1991, the Chesapeake Bay Program funded a two-year effort to develop estuarine water quality criteria for atrazine. The project included a comprehensive literature review of atrazine toxicity in Chesapeake Bay organisms and an investigation of the relationship of salinity to atrazine toxicity in two Bay organisms [108,109,121]. The result will be publication of estuarine water quality criteria for atrazine in 1994; EPA is also working on publication of freshwater and marine water quality criteria for atrazine. The approach used to develop the estuarine criteria for this herbicide will provide the necessary framework for the development of estuarine aquatic life criteria for other chemical contaminants in the Chesapeake Bay.

#### ***VIRGINIA PESTICIDE DISPOSAL PROGRAM***

In response to a comprehensive review of pesticide management in Virginia which showed

that the storage of unusable and banned pesticides represented a serious hazard to the environment, the Virginia Pesticide Control Board recognized the need for an agricultural pesticide disposal program. Three areas were selected for participation in a 1990 pilot project—Clarke, Frederick, and Northumberland counties. The final cost to collect, pack, transport, and dispose of the waste was \$158,977. The average cost per participant was \$2,304 and the average cost per pound of pesticide waste collected was \$5.26 (contracting costs only). Pesticides collected in the largest quantities during the pilot project were DDT (both in pure form and in combination with other insecticides), endrin, and lead arsenate. The total quantity of agricultural pesticide waste collected was 31,797 pounds. The average amount of pesticide waste per participant was 461 pounds. Based on a 1991 statewide survey of farmers, pesticide dealers, and small pest control firms, it is estimated that over 300,000 pounds of waste pesticide are stored by the agricultural community throughout Virginia.

Virginia Department of Agriculture and Consumer Services, in cooperation with the Virginia Pesticide Control Board, implemented a second pesticide disposal effort during 1992. Five areas were selected to participate in the 1992 Pesticide Disposal Program—Accomack, Nelson, Northampton, Nottoway, and Rockingham counties. The total quantity of pesticides collected during the program was 57,237 pounds. The final direct cost for conducting the 1992 program was \$225,264.10, including the contract costs of collection, packaging, transportation, and disposal (\$216,058.40) and state laboratory analysis of unknowns (\$9,205.70). The average cost per pound was approximately \$3.93 with the average cost per participant approximately \$1,179. The most common pesticide wastes collected included DDT, carbofuran, orthoxenol, disulfoton, and arsenic-containing pesticides.



## **Minimize Chemical Loadings**

### ***BAY BASIN HOUSEHOLD HAZARDOUS WASTE COLLECTION PROGRAMS***

Numerous local governments within the Bay watershed have undertaken successful household hazardous waste collection events. In Virginia, Fairfax County was one of the first areas to sponsor a collection day. Since 1985, the Fairfax County program has received waste from over 5,500 residents. Other collection days have been organized in Loudon County, Prince William County, and the City of Alexandria.

In Maryland, Anne Arundel County initiated its collection day program in 1988. The first event drew 466 cars bringing 23,264 pounds of waste to the collection site. Participation in subsequent events has grown to a present rate of over 1,000 participants at collection day events. Since the inception of Anne Arundel County's program, more than 4,100 residents have participated, resulting in the collection of over 350,000 pounds of household hazardous waste. The county's total cost for the program since 1988 is \$623,000 or approximately \$3,720 per ton.

Montgomery County, Maryland has had similar successes. Initiated in 1987, Montgomery County's program participation increased from 648 residents at its first event to 1,152 people in 1992. The county estimates its average cost to be approximately \$128 per vehicle served. Other Maryland collection events have occurred in Baltimore, Howard, Frederick, and Prince George's counties.

In 1993, the District of Columbia successfully conducted a household hazardous waste collection program. The program, sponsored by the Department of Public Works, attracted more than 1,000 participants. The district has a total of four one-day collection events scheduled annually.

In Pennsylvania, York County has provided its citizens with an annual household hazardous waste collection event since 1985. Due to ongoing education and publicity efforts, awareness and participation have increased each year. A recent event in 1991 was attended by 1,167 residents. The household hazardous waste was collected during two consecutive Saturdays in two different locations and was staffed by a contracted hazardous waste handling company. The 1991 collection days cost the county approximately \$242,000, \$237,000 of which was paid to the contractor for its services. The remaining \$5,000 was spent for publicity, distribution of household hazardous waste wheels, and employee time. The York County Solid Waste Management Authority funds the program.

Elsewhere in Pennsylvania, Lancaster County and the Northern Tier Solid Waste Authority are among the local governments participating in collection efforts. One of the few permanent facilities in the Bay watershed, Lancaster County's 1,200 square foot collection and storage building has numerous safety features. Two full-time staff accept the waste, classify it, store it on shelves, combine certain items (oil, paint, and anti-freeze), and fill out the necessary paperwork. At least once every 90 days the contracted hazardous waste hauler packs the waste in drums and ships them to an appropriate disposal facility. Some of these household wastes are deposited in hazardous waste landfills; others are incinerated or recycled.

### ***PENNSYLVANIA POLLUTION PREVENTION PROGRAM***

A Source Reduction Strategy Manual has been developed to help generators comply with the requirements and to achieve source reduction. The manual includes a discussion of the regulatory requirements, elements of a comprehensive source reduction program, the means to measure reduction, and ways to conduct a source reduc-

tion opportunity assessment. The Department of Environmental Resources is also in the process of developing a technical assistance program to help waste generators implement source reduction programs.

### **MARYLAND POLLUTION PREVENTION PROGRAM**

The Maryland Department of the Environment has received \$350,000 from the EPA to fund a multimedia pollution prevention program initiative during the past two years. Current projects include a collaboration with other state agencies to: 1) investigate the capital needs of small businesses for pollution prevention implementation; 2) develop industry-specific technical assistance; 3) design and present a series of pollution prevention seminars; and 4) create and present a multimedia technical cross-training curriculum for department staff.

### **MARYLAND INDUSTRIAL AND COMMERCIAL POLLUTION PREVENTION SUCCESSES**

To date, Maryland businesses have realized a number of successes in pollution prevention. The following are examples of the achievements the department encourages through integration of pollution prevention into its regulatory and non-regulatory programs.

*AAI Corporation, Cockeysville*, is a large manufacturer of systems for the military and federal government. A plating system that produces heavy metal-laden effluent has been fitted with an ion exchange system and complementary electrolytic recovery process. Rather than disposing of the raw effluent as hazardous waste, the metals are extracted for resale and recycling and the treated effluent is reused in the plating process.

*Better Engineering Manufacturing, Baltimore*, is a manufacturer of water-based cleaning equipment for industrial and automotive uses. The company's products replace solvent-based sys-

tems and are in use at government facilities and private businesses worldwide.

*Beretta, Accokeek*, is a small arms manufacturing operation that has significantly reduced the generation of hazardous waste through the introduction of and use of a treatment/metals recovery system that reduces the waste toxicity and volume of their metal plating operations. Further reductions can be attributed to the installation of a coolant recycling unit and the use of non-hazardous inks in the silk screen printer, which uses an evaporator to reduce the volume of lead in wastewater.

*Black & Decker, Easton*, is a facility that manufactures metal tools, small motors, and other machine parts. The company has eliminated the use of 1,1,1-trichloroethane by using equipment manufactured by Better Engineering Manufacturing. Better Engineering Manufacturing's jet washer design encompasses a turn table on which the parts are placed, rotated, and cleaned with a biodegradable detergent and water solution. In another example of source reduction through solvents replacement, this new operation has eliminated emissions from previously used solvent cleaner and substantially reduced the costs and liabilities of waste disposal.

*Cambridge Incorporated, Cambridge*, a manufacturing operation that fabricates wire cloth for a conveyor product line and has been recognized by the Maryland Department of the Environment as an outstanding example of hazardous waste source reduction. Cambridge implemented an aqueous-based system for cleaning belts and other products as an alternative to its old solvent cleaning system, eliminating use of the organic solvent trichloroethane. Wash/rinse tanks now contain detergent and deionized water along with electric immersion heaters, oil skimmers, and turbo-chargers to aid the degreasing process. With lower operating costs and total elimination of contaminated solvents, Cambridge estimates the payback period for the cost and installation of the new system to be slightly over four years. In addition to cost and environmental benefits, lowered risk

to employees was also cited as a factor in the company's decision to eliminate the use of trichloroethane.

*Ecoprint, Silver Spring*, is a small printing company that received an EPA grant of \$25,000 to develop an extremely low metal content ink in 1992. In conjunction with a Chicago-based ink manufacturer, Ecoprint reformulated ink pigments with the metal content reduced from the hundreds or thousands of parts per million to pigments with five to ten parts per million. This modification means that not only is less metal used in the ink manufacturing, but less metal is released to the environment through incineration, burial in landfills, or as a residual product of paper recycling.

*MID Atlantic Finishing, Capital Heights*, is a plating company that has reduced the toxicity and volume of its hazardous waste. In addition to the treatment of waste from the plating line, the rinse water is passed through an ion exchange system that removes waste metals. The clean effluent is then recycled back into the rinse section of the plating operation. This action reduces the amount of hazardous waste requiring disposal and fresh water required for the rinse operation.

*Rocky Top Wood Preservers, Inc., Hagerstown*, is a lumber pressure treatment facility that has taken comprehensive measures to minimize hazardous waste and to recycle all generated wastes. Company efforts include a shaker system to remove debris from the initial delivery of lumber. The facility has a tapered concrete floor with drains that collect and return effluent from the drip pad for recycling in a later charge. As a matter of routine operations, work vehicles are limited to particular service areas to prevent carry-over contamination of dirt and dust from entering the service charge and drip-drying areas. The facility offers an excellent example of pollution prevention principles applied in plant design and operation.

*Vulcan-Hart Company, Essex*, has converted its solvent-based wet paint operation to a powder

paint process. Factors which led to the change to powder-based paints included meeting the Clean Air Act thresholds for air emissions, reducing cost and liability for disposal of hazardous waste sludge, and realizing overall quality and cost benefits of the powder-based paint system. In addition to being more energy efficient, the powder-based paint operation is also readily adaptable to the recovery and reuse of waste powder. Overall operating and maintenance costs are also lower than costs associated with the wet paint system. Along with exceeding minimal compliance limits and reducing worker risk, the company expects financial payback on its investment within three years.

### ***VIRGINIA POLLUTION PREVENTION PROGRAM***

Soon after the Virginia Department of Waste Management was created in 1986, the Waste Management Board recommended the establishment of a pollution prevention technical assistance program, based upon a recommendation by the Virginia Toxics Roundtable. The 1988 General Assembly appropriated funds for the establishment of the Waste Reduction Assistance Program—a voluntary program designed to reduce Virginia's waste and prevent pollution of the air, land, and water. Program clients include Virginia industries, local and state governments, and institutions, among others. To date, the focus has been primarily on gathering, consolidating, and disseminating existing waste reduction materials. This program will continue to play a prominent role in promoting pollution prevention within the Virginia Department of Environmental Quality—organized to facilitate pollution prevention.

In 1990, the Virginia Department of Waste Management received a \$300,000 multi-year pollution prevention grant from the EPA. The grant funded the Interagency Multimedia Pollution Prevention Project which supported multimedia pollution prevention efforts and involved staff from the Virginia Department of

Waste Management, Virginia Department of Air Pollution Control, and the Virginia State Water Control Board.

### ***VIRGINIA INDUSTRIAL AND COMMERCIAL POLLUTION PREVENTION SUCCESSES***

*Automata, Sterling*, is a circuit board manufacturer committed to pollution prevention. The company has eliminated methylene chloride and 1,1,1-trichloroethane from its production processes and has instituted engineering systems to reduce waste production.

*AT&T, Richmond*, converted from solvent-based production to aqueous-based production of circuit boards eliminating the need to use methylene chloride and trichloroethane solvents. Prior to the change, the facility purchased approximately four million pounds of solvent annually which ultimately resulted in the production of hazardous waste or release of atmospheric emissions.

*Colonial Circuit, Fredericksburg*, changed its plating operations wastewater pretreatment process and achieved a reduction of 80,000 pounds of hazardous waste per year. The old system generated approximately 90,000 pounds of a hazardous waste sludge that was sent out-of-state for land disposal. The new ion-exchange system produces a metallic product that can be reused in the process. The cost of the new system was under \$100,000 and paid for itself in less than two years through reduced hazardous waste disposal costs. The quality of the wastewater discharged from the facility also improved.

*C.R. Hudgins, Lynchburg*, is a medium-sized, privately-owned company that has significantly reduced the amount of hazardous waste generated by continually improving its operating procedures and housekeeping practices. By automating its plating processes and implementing the newest techniques to reduce the amount of carry-over from the plating tanks to the rinse process, the company reduced the amount of

hazardous waste generated from 1987 to 1989 by 41 percent. This reduction also prevented more than one million pounds of hazardous waste from being sent to a landfill. In July 1993, the facility announced a \$2.2 million expansion.

*DuPont Spruance, Richmond*, instituted source reduction and recycling efforts within their Kevlar production process that reduced generated hazardous waste by more than 80 percent. Additionally, organic emissions were reduced by 7 percent over a three-year period.

*DuPont, Waynesboro*, won a Virginia Governor's Environmental Excellence Award for its commitment to pollution prevention and recycling. Through distillation and reclamation, almost all hazardous materials are recovered and reused in the company's processes. Retrofitting old gaskets has eliminated most fugitive air releases. The facility has also reduced polymer and yarn waste by using waste exchanges. In addition, DuPont has extended its environmental programs to the surrounding community.

*Ericsson GEMobile Communications, Lynchburg*, manufactures land radios, cellular phones, mobile telephones, and mobile data units. In 1987, the company was using four different solvents for circuit board cleaning. By 1992, it was only using freon. Through the use of a no-clean flux soldering process it eliminated the use of freon in 1993. The small amount of cleaning required is done using alcohols. The facility has committed to EPA's 33/50 program and is well ahead of the 33/50 goals. Ericsson GE also has an aggressive solid waste program, recycling 100% of its paper and cardboard as well as thousands of pounds of radio scrap.

*Expert-Brown, Richmond*, was the first printer in Virginia to employ a new waterless printing technology that reduces waste paper by approximately one-fourth of previous levels and reduces water use and waste from fountain solutions. The company has an environmental ethic which covers all aspects of its operation, using aqueous

developers, non-alcohol fountains in its non-waterless presses, and both recycling film and press wipes.

*Ford Motor Company, Norfolk*, has implemented numerous pollution prevention changes over the past several years. Some of the changes include: switching to high solids paints; significantly reducing volatile organic compound emissions; using gasoline vapor recovery in fueling operations; and eliminating or dramatically reducing the use of 1,1,1-trichloroethane, iron cyanide, lead, chromium, and all chlorofluorocarbons. The facility uses several pollution prevention support committees to continuously improve its pollution prevention efforts.

*Lewis Creative Technologies, Richmond*, a small commercial printer, has reduced the amount of waste produced through the extensive use of computerized pre-press technology. Desktop publishing reduces the paper waste from paste-up; direct-to-film technology eliminates the need for photographic paper altogether. The company is also an environmental leader in other areas, using less hazardous blanket cleaners, aqueous developers, and two-sided offset plates. The company expects to expand soon into direct-to-plate technology, eliminating the need for film which will remove all silver from its waste stream.

*Madison Wood Preservers, Madison*, a lumber pressure-treating facility, has been recognized by the EPA for its leadership in pollution prevention. The company has developed a new closed-loop system that continually recycles water and preservatives, filtering and restrengthening the mixture. In addition, Madison Wood Preservers has also added a third step to the normal two-step moisture-removing process that minimizes unusable materials and the waste from rejects.

*Pier IX, Newport News*, is a coal storage facility that developed an innovative stormwater collection system, preventing coal dust runoff from entering the James River. The company won a 1991 Virginia Governor's Environmental Excellence Award.

*Reynolds Metals, Bellwood Printing*, pioneered the use of water-based inks in the early 1980s. Since then, the Bellwood facility has found water-based substitutes for foil inks, paper inks, primers, protective overcoats, glues, and thermoset adhesives. Reynolds has measured reductions of 97.3 percent in volatile organic compounds and reductions in hazardous air pollutants of 94 percent since 1983. In addition, innovative recycling programs that include reblending waste ink for use as backprint ink have been implemented.

*Richmond Newspapers, Mechanicsville*, opened a \$171 million printing facility in 1991 that was designed to achieve the highest environmental standards. Volatile organic compound emissions have been dramatically reduced through the use of a dry blanket waste system. Virtually no hazardous waste is generated as a result of a comprehensive waste ink recycling program. In addition, the company recycles all other waste materials created by the facility. Half of the newsprint used is 100 percent recycled. Environmental stewardship at the company extends to facility management (e.g., Stage II vapor recovery at the refueling island, energy conservation via computer controlled heating and cooling systems, and automated lighting automation systems) and landscaping (e.g., non-potable water in landscaping and sprinkling and wetlands creation and maintenance).

*William Byrd Press, Richmond*, has reduced the amount of hazardous waste generated by more than 60 percent over the past 5 years through the use of an ink reclamation system.

*Schuller International, Edinburg*, produces roofing materials using old telephone books and lottery tickets as raw materials. The company continues to expand the amount of recyclable materials used in its products.

*Union Camp, Richmond*, has eliminated solvent use at its facility through the use of water-based adhesives.



# REFINEMENTS TO THE BASINWIDE STRATEGY

## Pollution Prevention

### Targeting Industrial/ Commercial Sector Pollution Prevention Actions

Building upon existing state and federal efforts to encourage adoption of pollution prevention approaches, findings from the reevaluation of the 1989 Basinwide Toxics Reduction Strategy should be used to target prevention opportunities. Geographically targeting Regions of Concern and Areas of Emphasis is one example of applying the practical use of new knowledge on the nature, magnitude and extent of Bay toxic problems.

The revised strategy needs to take advantage of the existing and often extensive institutional structures within the industrial manufacturing and commercial sectors, rather than attempting to create a new and overlapping infrastructure. Many of these existing institutional structures (e.g., statewide chambers of commerce) already have a strong commitment to the adoption of pollution prevention approaches by their members. A strong link between the strategy reevaluation findings and these existing commitments to pollution prevention should be forged within the revised strategy.

### Public/Private Partnership for Integrated Pest Management Implementation

Integrated pest management is a decision-making process that uses regular monitoring to determine if and when pesticide treatments are needed. This type of management employs physical, mechanical, cultural, biological, and educational methods, keeping pest numbers low

enough to prevent intolerable damage or annoyance. Treatments are applied only where monitoring has indicated that the pest will cause unacceptable economic, medical, or aesthetic damage. Chemicals with the lowest toxicity are used as a last resort.

Integrated pest management requires the collection of site-specific information to improve decision-making skills and facilitate the selection of appropriate pest management alternatives. Effective integrated pest management strategies involve the wise and appropriate use of chemicals as a defense against pests with populations that cannot otherwise be controlled. These strategies do not advocate the complete elimination of pesticides.

In urban landscape, turf, recreational and structural settings, the adoption of integrated pest management is similar to agriculture. In agricultural settings, pesticide use is tempered by the economics of production and the lifelong experience of growers. In urban settings, where treatment areas are small and scientific knowledge of pesticide impacts is lacking, aesthetics rather than economics determine pesticide use. Surveys indicate that urban pesticide use per acre is comparable or higher than agricultural use and that the pesticide load per person is also greater.

In both the urban and agricultural settings, the greatest impediment to implementation of integrated pest management is the availability of experts beyond cooperative extension agents. Such an alternative or supplemental source of expertise exists within commercial, agrichemical dealerships and urban pest control services. Most of these people have extensive experience, although many would require more specialized training in integrated pest management. Currently, few businesses are adequately staffed to provide individualized

site monitoring at the intensity recommended in integrated pest management scouting programs. Despite the staff and training limitations, these businesses have tremendous potential to influence the overall adoption of integrated pest management.

In partnership with private interests, a two-pronged approach could be taken. Agricultural agencies could ensure that a system for professional crop advisor certification is available throughout the region, with the private sector providing trained, certified experts throughout the Bay basin. In working with the agricultural community and private sector on nutrient management and soil conservation plans, integrated pest management planning could become a logical and integral component of whole farm planning efforts.

## **Regulatory Program Implementation**

Building on the progress of regulatory program implementation to date, the revised strategy needs to be consistent with and supplement the existing state, federal, and local legislative and regulatory mandates. Regulatory programs should be targeted towards Bay toxics problems as identified through the strategy reevaluation and, therefore, place emphasis on Toxics of Concern, Regions of Concern, and significant sources of inventoried chemical loadings and releases.

### **Focus on Chesapeake Bay Toxics of Concern**

Future revisions of the Toxics of Concern List should include the latest Chesapeake Bay Program information on point and nonpoint source loadings, ambient concentrations, aquatic toxicity, and federal and state regulations and/or restrictions. The process for reviewing and revising the Toxics of Concern List (e.g., adding or removing chemicals from the list) must be based

on an objective, risk-based ranking system followed by professional interpretation of the resultant rankings.

Revision of the Toxics of Concern List should also include identification of chemicals of potential concern for the Chesapeake Bay basin. Given collection of additional data and information, these compounds would be considered for future placement on the Toxics of Concern list. Ranking the comprehensive list of Bay basin potentially toxic chemicals using a risk-based system would help identify those chemicals which don't rank in the top few percent but may pose a threat in the future (based on a set of selection guidelines). A chemical could be placed on this secondary list due to increasing use (in the case of a pesticide) or anticipated increases in loadings (for a compound associated with increases in population and changes in land use).

Increased reliance on the identified Toxics of Concern and Chemicals of Potential Concern would enable agency managers to anticipate (rather than react to) chemical-specific related issues. Possible actions range from aggressive implementation of a pollution prevention program targeted at specific sources of the identified chemical contaminants to the implementation of discharge permit limits before the targeted chemical contaminants become widespread in the Bay basin environment.

## **Regional Focus**

The most severe toxics contamination problems in the Chesapeake Bay are geographically limited to areas with known adverse impacts—the Patapsco, Anacostia, and Elizabeth rivers—often located near urban centers that are close to the Bay. Through the strategy reevaluation process, an in-depth analysis of existing data has identified other Bay habitats where lower concentrations of chemicals may have a chronic effect (e.g., reduced growth or reproduction) rather than an acute impact (e.g., death) or where present



activities may lead to the development of toxics-related problems in the future if action is not taken now.

The concept of geographically targeting areas with toxics-related problems for toxics reduction and prevention activities is not unique to the Chesapeake Bay region. This approach has been utilized successfully in the Great Lakes and the Puget Sound to focus limited resources on those areas most affected by toxic chemicals. A geographical targeting approach could play a critical role in future strategy implementation of specific reduction and prevention actions within the Chesapeake Bay basin.

Without a geographical focus, however, the revised strategy could cover too many areas and issues to be effective. The identification of Regions of Concern will narrow the scope to definable areas on which to focus specific actions. At the same time, the Regions of Concern approach is meant to go beyond obvious sites of contamination to include areas that are less impacted but are still considered problematic. Regions with evidence of potential chemical contaminant-related impacts would also be identified as Areas of Emphasis and targeted for more prevention-oriented actions. The identification of Regions of Concern and Areas of Emphasis will clarify the geographic extent of Chesapeake Bay toxics problems and establish a basis for targeting reduction and prevention actions and defining future assessment, monitoring, and research priorities.

In a recent issue paper entitled *Chesapeake Bay Regions of Concern: A Geographical Targeting Approach to Toxics Reduction and Prevention*, a Region of Concern was initially defined as “a delineated area within the tidal boundaries of the Bay and its tributaries within which available information indicates that chemicals are either adversely impacting the Bay system or for which the reasonable potential to do so exists” [297]. Decisions on designation of these regions will be made by evaluating available data and information within a set of criteria which

reflect impacts or the significant potential for impacts on Bay habitats, living resources, and human health, with a focus on those areas showing multiple effects. Criteria under consideration include water column contamination, water column toxicity, sediment contamination, sediment toxicity, fish and shellfish tissue contamination, and benthic community structure. A protocol for the identification and delineation of Regions of Concern will be developed in advance of the 1994 Chesapeake Executive Council meeting.

Once designated, the Regions of Concern (areas with known toxic impacts) and the Areas of Emphasis (areas with the potential to develop serious chemical contaminant-related impacts) will be focal points for multi-agency cooperative efforts in specific toxics assessment, reduction, and prevention within the tidal waters of the Chesapeake Bay. This approach will ensure a geographical focus for the development of more specific reduction and prevention action plans based on the identification of areas which are most impacted or likely to be impacted by chemical contaminants. The Chesapeake Executive Council has already directed development of Regional Action Plans for three designated Regions of Concern: Baltimore Harbor, Anacostia River, and Elizabeth River [54]. This increased geographical specificity will promote more local involvement and citizen participation in implementation of the revised strategy. By reducing and preventing chemical contaminant loadings and releases, the ultimate goal of minimizing and eventually eliminating adverse impacts on living resources within the Regions of Concern and the Chesapeake Bay can be realized.

## Directed Toxics Assessments

The strategy reevaluation has revealed the potential exists for the low levels of chemical contaminants in many Bay habitats to affect the Bay's living resources adversely. These levels,

are concentrations lower than thresholds generally associated with known toxic effects on living resources (e.g., EPA aquatic life criteria and state water quality standards) and elevated above natural background levels (e.g., enrichment of metal concentrations in sediment above natural earth crustal levels). Future assessments must focus on the risks posed to the Bay's living resources and the ecosystem due to low level chemical exposure, including the potential for additive or synergistic effects from multiple chemicals. These assessment must use chemical and biological methods with sufficient sensitivity to detect these effects.

Future transport and fate studies should focus on the following areas:

- **Chemical speciation/bioavailability:** Large gaps exist in our ability to distinguish between the total quantity of a chemical contaminant in the system and the percentage of that contaminant available for biological uptake.
- **Sediment transport/resuspension:** The rapid and persistent resuspension of particle-bound contaminants affects contaminant residence time and fate.
- **Trophic accumulation:** Biological and ecological factors which govern the accumulation and transfer of chemicals through Bay food webs are still largely unknown.
- **High quality measurements of chemical contaminant loadings and extant concentrations:** Many of the loading estimates for important chemical contaminants are based upon data of questionable quality. In addition, little information is available concerning concentrations in the Bay.

Future trophic transfer studies should focus on the following areas:

- **Uptake and transfer:** The factors that govern uptake and incorporation by microbes and

phytoplankton are fairly well known. The same factors for higher trophic levels are not well understood and need to be examined.

- **Differences between pelagic and benthic pathways:** Benthic invertebrates have several feeding patterns which affect their exposure to chemical contaminants. In addition, trophic linkages in the water column are likely to be driven by different processes. Studies that compare and contrast those processes important in regulating exposure need to be conducted.
- **Indirect effects due to trophic interactions:** Shifts in prey species abundance caused by exposure to contaminants can result in altered feeding strategies and predator communities which, in turn, can affect contaminant transfer within the food web. The importance of such indirect processes is poorly understood.

Future studies of effects should focus on understanding the interactive and cumulative effects of low levels of chemicals, both anthropogenic and natural in origin, on the Bay's living resources.

## **Ambient Toxicity/ Community Assessments**

The relationship between chemical loadings or ambient concentrations in water column and bottom sediment habitats and cumulative biological effects from chemical exposure has not been clearly demonstrated. Determining chemical contaminant-related adverse effects on living resources in natural habitats can be most realistically accomplished by the direct measurement of biological responses in ambient media. To measure progress in achieving the revised strategy goals, agencies must be able to evaluate the effects of exposure to low levels of chemical contaminants. The ambient toxicity assessment program uses biological indicators to detect adverse effects of ambient conditions on the Bay's living resources.

The use of biologically relevant endpoints (e.g., reduced reproduction) provides an integrated measure of toxic conditions. The traditional approach of chemical-specific monitoring does not provide such a measure as the bioavailable fraction of a chemical contaminant is often unknown or not directly measurable. If no significant biological effects are reported on the living resources, then the chemical contaminants are not available at biologically adverse concentrations.

As a logical extension of existing Toxicity Identification and Reduction Evaluation procedures directed at point source discharges, ambient toxicity testing can confirm that a contaminant problem from a point source has been eliminated. Ambient toxicity testing can also provide additional assessment of the level of protection present beyond the mixing zone—valuable information not currently obtained from traditional effluent toxicity testing.

Since nonpoint source inputs of chemical contaminants are now recognized as significant, agencies must look beyond point sources for the cause of the impacts. When biological indices (i.e., fish or benthic indices of biological integrity) indicate stressed communities, toxicity assessments can be used to provide additional data to identify reasons for the stress. This coupled approach may indicate that additional investigation into possible point and nonpoint sources is needed. Such information would aid agency managers in targeting reduction and prevention actions.

Ambient toxicity testing must also be coupled with in-field biological assessments to match “impact-predicted” responses based on ambient toxicity data with “impact-observed” responses based on biological assessments. Where biological community indices indicate stress, the ambient toxicity testing could help determine whether the source of the stress is related to chemical contaminant exposure.

Future ambient toxicity/in-field biological assessments should be used to further delineate identified Regions of Concern and Areas of Emphasis and can be used to determine if other regions should be identified and targeted for reduction and prevention actions. These assessments may verify or eliminate exposure to chemical contaminants as a cause for stressed living resource communities in critical Bay habitats.

## **Better Estimation of Chemical Loadings and Releases**

The reported loadings and releases for many of the sources inventoried in the *Basinwide Toxics Loading and Release Inventory* were not collected to calculate load or release estimates, but to assess compliance (e.g., point sources), use patterns (e.g., pesticide applications), or for other purposes. To develop a comprehensive baseline of chemical loadings and releases to the Bay basin, the following must be accomplished: 1) ongoing and future loading estimation studies and monitoring programs should use consistent chemical fractions or sets of fractions (e.g., total, total recoverable, dissolved, particulate) across all potential loading sources; 2) sample collection methods used should minimize sample contamination (since contamination yields higher load estimates); and 3) analytical methods that yield lower detection limits (which will ensure more definitive loading estimates) should be used.

### **POINT SOURCES**

- State and federal compliance monitoring programs should collect data necessary to ensure that dischargers comply with permitted discharges. These programs should also provide information (i.e. flow, concentration) needed to develop individual facility loading estimates for chemical contaminants.
- A system for routine state submission of point source discharge data should be implemented.

- The basinwide inventory should include loading estimates for all individual point source facilities discharging to waters within the Bay basin. The estimates should be based initially on available data and eventually on data collected for calculating facility-specific loading estimates.
- Improve estimates of “dry” atmospheric deposition loadings of chemical contaminants.
- Improve estimates of atmospheric deposition fluxes of pesticides.
- Conduct intensive deposition studies to determine the sources of atmospherically deposited chemical contaminants and the fate and bioavailability of these chemical contaminants.

### ***URBAN STORMWATER RUNOFF***

- Establish, coordinate, and implement comparable sampling, load estimation, and reporting procedures for the collection and analysis of stormwater runoff data for large municipal populations within the Bay basin.
- Account for the effectiveness of the structural and non-structural stormwater management practices in use throughout the Bay basin when revising the inventory’s estimates of urban stormwater loadings of chemical contaminants.
- Develop estimates of atmospheric deposition loadings of chemicals to above fall line land and water surfaces and to below fall line land surfaces.

### ***PESTICIDES***

- Develop and apply a standard survey questionnaire for all Bay basin jurisdictions using common survey parameters and report the results to a single data base in a consistent format.
- Conduct coordinated state studies to link pesticide use estimates to the amount of pesticides delivered to tributaries, groundwater, and Bay tidal waters. These studies should focus on major crops (e.g., corn) and land use (e.g., suburban residential) that use significant quantities of pesticides.
- Design watershed-specific monitoring projects to develop data bases that will provide the information necessary to assess the accuracy of predictive models linking pesticide applications with pesticide loadings to tidal surface waters.

### ***FALL LINE LOADINGS***

- Ensure loadings of metals, organic chemical contaminants, and pesticides are fully characterized in terms of fraction (dissolved vs. particulate) and flow (baseflow vs. storm flow) for the three major Bay tributaries—Susquehanna, Potomac, and James rivers—which jointly contribute more than 80 percent of the freshwater flow.
- Conduct necessary fall line monitoring to estimate loadings of chemical contaminants from the remaining tributary fall lines—Patuxent, Rappahannock, Mattaponi, Pamunkey, Appomattox, and Choptank rivers.

### ***ATMOSPHERIC DEPOSITION***

- Monitor to estimate atmospheric deposition loadings contributed from local urbanized areas (e.g., Baltimore, Norfolk/Hampton Roads) to Bay tidal waters and the surrounding watershed.

### ***SHIPPING/TRANSPORT/BOATING/MARINAS***

- Develop chemical loadings estimates for those shipping, boating, and marina activities and structures (including pressure-treated wood) that have the highest potential to impact the Bay adversely.

## **Targeting Source Reduction/ Prevention Through Mass Balancing**

With increasingly stringent controls on conventional (i.e., point) sources of chemicals, the relative importance of diffuse nonpoint sources is increasing. More precise accounting of both human-generated and natural chemical contaminant loads to the Bay is critical in understanding how chemicals cycle within the ecosystem and the ultimate effect of these chemicals on the living resources. The magnitude of inputs and outputs of chemicals must be determined to have successful and cost-effective control strategies.

Establishment of a “mass balance” for Chesapeake Bay would provide an appropriate conceptual framework to estimate the relative importance of the sources of chemical contaminants to the Bay. In such a model, quantities of a chemical entering and exiting the water body by various pathways are determined. The framework would provide a means by which to array and interpret data from a diverse arrays monitoring, modeling, research, and load estimation studies, projects, and programs [13].

Investments in load estimation studies would need to be coupled with efforts to better estimate the removal rates (e.g., losses resulting from burial, gas exchange, degradation) from Chesapeake Bay. A better understanding of the time lag between reduction or prevention of chemical loadings and a corresponding reduction in the concentration of chemicals in the sediments and overlying water column are critical to support risk reduction-based decisions on what chemical contaminants to reduce, from where, by how much, and over what time period.

The mass balance approach should be an integral part of the Regions of Concern component of the revised strategy. It is not necessary or advisable to develop a definitive mass balance for a region. Rather, the mass balance approach should identify the relative importance of various sources of chemical contaminant-related impacts so that effective risk-reduction strategies can be developed. As this approach is used in the various Regions of Concern, it may point toward more comprehensive risk management strategies for the basin as a whole.



## TOWARDS A REVISED STRATEGY

Based on the findings of the strategy reevaluation report, the Chesapeake Executive Council directed the Bay Agreement signatories to revise the existing Basinwide Toxics Reduction Strategy by the next annual Executive Council meeting (Table 50) [54]. During its September 1993 meeting, the Executive Council further directed that the revised strategy emphasize four areas: pollution prevention, regulatory program implementation, regional focus, and directed toxics assessments. The process for revising the basinwide strategy will incorporate broad public

involvement in the strategy's development, review, and implementation. The revised strategy will build upon the findings from the strategy reevaluation and be structured around the Executive Council's four areas of emphasis. Following a series of stakeholder roundtables and a public review of the draft strategy document, the final strategy will be presented to the Chesapeake Executive Council at their 1994 annual meeting for signature and adoption by the Chesapeake Bay Agreement signatories.

**Table 50.** Chesapeake Executive Council Toxics Reduction Strategy Reevaluation Directive

### Chesapeake Executive Council Toxics Reduction Strategy Reevaluation Directive

In January 1989, the Chesapeake Executive Council adopted the Basinwide Toxics Reduction Strategy in fulfillment of the 1987 Chesapeake Bay Agreement and committed to reevaluate the Strategy in 1992. The long term goal of the Strategy is to work towards a toxics free Bay. The strategy uses the requirements of the 1987 Clean Water Act as a foundation for action and initiates a multi-jurisdictional effort to better define the nature, extent, and magnitude, of toxic problems.

Through the strategy reevaluation, it has been determined that:

- In some locations, toxic problems exist in the Chesapeake Bay. The nature, extent, and severity of toxic impacts range widely throughout the Bay: a few well known areas have serious, localized problems; and, some other regions that were previously thought to be uncontaminated have shown some toxic effects.
- No evidence was found of severe, systemwide responses to toxics similar in magnitude to the observed effects throughout the Bay due to excessive levels of nutrients, such as declines in underwater grasses and widespread low dissolved oxygen conditions.
- Existing programs are reducing the input of toxics to the Chesapeake Bay.
- Concentrations of some toxic substances in fish, shellfish, wildlife and their habitats are on the decline although elevated levels are observed in several urbanized regions.
- Widespread areas have low levels of toxic substances below thresholds associated with adverse effects on the Bay's living resources. The long term effects from these low levels remain unclear.

The reevaluation has shown that significant steps toward controlling the input of toxics to the Bay system have been taken over the past decade. However, much remains to be done to address the known and potential problems identified by the reevaluation. We should therefore pursue the

**Table 50 (con't.)** Chesapeake Executive Council Toxics Reduction Strategy Reevaluation Directive

following directions in the development of a strategy to protect the Bay and its resources from toxic pollution: increase emphasis on pollution prevention; supplement regulatory programs; use a regional focus to address problem areas; and focus assessments in direct support of management actions.

Therefore, the Chesapeake Executive Council directs the Bay Agreement signatories to revise, by the next annual Council Meeting, the existing Basinwide Toxics Reduction Strategy through a process that incorporates broad public involvement in the Strategy's development, review, and implementation. Further, the Council directs that emphasis be placed on the following four areas:

**1. Pollution prevention**

The revised Basinwide Toxics Reduction Strategy shall recognize pollution prevention as the preferred approach to reducing risks to human health and living resources due to exposure to toxics within the Chesapeake Bay region. The revised Strategy shall:

- Promote pollution prevention education and technical assistance programs within all levels of government—federal, state, and local—throughout the Chesapeake Bay watershed;
- Expand support of integrated pest management programs for controlling and minimizing pesticide use in agricultural, urban, and suburban areas;
- Create additional incentives for industry and advance technical assistance, training, and outreach opportunities to aid industry with incorporating pollution prevention actions into their daily business activities;
- Continue to integrate pollution prevention approaches into environmental regulatory programs wherever feasible; and,
- Use pollution prevention as the principal means to offset increases in toxics loadings due to land use changes and population growth in the Bay basin.

**2. Regulatory program implementation**

The revised Basinwide Toxics Reduction Strategy shall be consistent with, and supplement, the requirements of the Clean Water Act (CWA) and the Clean Air Act (CAA) to ensure protection of human and living resources. The revised Strategy shall:

- Support the CWA and CAA regulatory programs through recognition and promotion of the toxic reduction actions taken throughout the Chesapeake Bay watershed;
- Quantify toxics reductions from ongoing implementation of CWA and CAA programs and anticipated habitat and living resources improvements;
- Focus Chesapeake Bay Program commitments on toxics reduction and prevention actions; and,
- Undertake additional actions needed beyond requirements of the CWA and CAA to achieve the goals of the Chesapeake Bay Agreement and the revised Strategy.



**Table 50 (con't.)** Chesapeake Executive Council Toxics Reduction Strategy Reevaluation Directive

**3. Regional focus**

The revised Basinwide Toxics Reduction Strategy shall direct reduction and prevention actions toward regional areas with known toxic problems as well as areas where significant potential exists for toxic impacts on living resources and habitats. At this time the Elizabeth River, Baltimore Harbor, and the Anacostia River are designated as the initial Chesapeake Bay Regions of Concern. Action plans to address the problems related to toxics in these three systems shall be developed by the next annual meeting of the Council. In addition, the revised Strategy shall:

- Establish a process for characterizing and designating additional areas of the Bay as Regions of Concern; and,
- Focus multi-agency cooperative efforts toward planning and implementing the necessary assessment, reduction, remediation, and prevention actions to restore and protect the designated Regions of Concern.

**4. Directed toxics assessments**

The revised Basinwide Toxics Reduction Strategy shall ensure that toxics assessments will directly support management decisions for the reduction and prevention of toxics. The initial baseline inventory of toxics loading and release sources by facility will be completed by April 1, 1994 to allow measurement of progress towards the Strategy goals. In addition, the revised Strategy shall:

- Require assessments of the potential impacts on the Bay's living resources from the observed widespread low level concentrations of toxics in Bay habitats.

Source: Chesapeake Executive Council 1993.



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## **APPENDIX A**

### **State Regulatory/Management Program Implementation Progress - Expanded Descriptions**



# Pennsylvania

## Water Quality Standards Program

The Pennsylvania Department of Environmental Resources regulates chemicals through Chapter 93 (Water Quality Standards) and Chapter 16 (Water Quality Management Strategy-Statement of Policy), both of which are codified in the PA Code. These requirements serve as the basis for water quality effluent limitations incorporated into NPDES permits and other regulatory actions to protect water uses.

Chapter 93 is reviewed and revised, if necessary, during each Triennial Water Quality Standards review mandated by Section 303(c) of the Clean Water Act. Chapter 16, which includes listings of numeric criteria and analytical detection limits, is reviewed and revised at intervals not exceeding one year. These reviews include public participation that meets EPA requirements.

As part of the Triennial Water Quality Standards review, Pennsylvania adopted a new comprehensive toxics regulation and statement of policy on March 11, 1989. The EPA approved these actions on April 11, 1990. The requirements apply to all discharges to the commonwealth waters, including those in the Chesapeake Bay Basin.

Section 93.8a (Toxic Substances) within Chapter 93 (Water Quality Standards) provides an improved and strengthened regulatory basis for controlling toxic discharges. It identifies reasons for controlling toxics, the type of substances to be controlled, design conditions, and risk management levels, while providing a basis for the development of criteria.

Chapter 16 Water Quality Toxics Management Strategy - Statement of Policy is a water quality policy for regulating toxic pollutants in wastewater discharges. Subchapter A of the strategy sets forth guidelines for the development of criteria for chemicals and lists the water quality criteria for toxic chemicals. Subchapter B lists associated analytical methods and detection levels.

Subchapter A establishes guidelines for criteria Federal Clean Water Act, Section 307(a) Priority Pollutants and any other chemical which the department determines is a concern due to its presence in wastewater discharges. These guidelines are divided into two categories—one for the development of aquatic life criteria and the other for the development of human health criteria. The human health criteria are further subdivided into threshold and non-threshold categories. Subchapter B is a compilation of data on the analytical methods and minimum detection limits for the Priority Pollutants and some other chemicals. Most methods are EPA-approved, but another may be listed in some cases in which EPA has no approved method.

These requirements serve primarily as the basis for the issuance of NPDES permit water quality-based effluent limitations, as well as compliance actions related to wastewater discharges. The summarized provisions included in Chapter 93 and Chapter 16 are as follows:

### Chapter 93 Water Quality Standards, Section 93.8a Toxic Substances

- Prohibits discharge of chemicals in toxic amounts.
- Defines chemicals as Priority Pollutants and any others identified by the department.

- Provides a basis for development of human health criteria threshold and non-threshold toxics.
- Establishes a health risk management level of one excess cancer in a population of one million ( $1 \times 10^6$ ) over a 70-year lifetime.
- Provides a basis for development of aquatic life criteria using EPA criteria when available or uses an application factor times 48 or 96 hours LC50 for representative important species.
- Allows the department to consider synergistic, antagonistic and additive impacts.
- Establishes design conditions to meet criteria.
- Allows the department to require effluent toxicity testing when necessary and to establish effluent limits based on this testing.
- Specifically incorporates, by reference, Chapter 16 under which the water quality criteria for toxics are established. The Pennsylvania Bulletin publishes the changes annually.

Chapter 16 Water Quality Toxics Management Strategy - Statement of Policy

- Provides guidelines for development of aquatic life criteria. Addresses short-term effects by the application of criterion maximum concentration (CMC) and criterion continuous concentration (CCC) for protection of aquatic life.
- Provides guidelines for the development of human health-based criteria. Addresses threshold level and non-threshold (cancer) toxic effects.
- Includes Table 1 (Water Quality Criteria for Toxic Substances).
- Addresses approved analytical methods and detection limits.
- Includes Table 2 (Approved EPA Analytical Methods and Detection limits).
- Includes Table 3 (Description of EPA Methods for the Analysis of Priority Pollutants).

As a minimum, Chapter 93 is reviewed and, if necessary, revised during each Triennial Water Quality Standards review mandated by Section 303(c) of the Clean Water Act. This review considers the need to incorporate new or revised water quality criteria for statewide applicability and other issues or policies of statewide concern. Revisions to water use designations and the criteria appropriate to protect these uses are made as use attainability studies are completed. Appropriate regulatory action and public participation, including a public hearing when necessary, are included in the review and revisions. Chapter 16, which includes listings of numeric criteria and analytical detection limits, is reviewed and revised at intervals not exceeding one year. All changes involve appropriate public participation including a public hearing. The Pennsylvania Bulletin publishes the results of these reviews.

The department conducts a water quality assessment program which includes the collection of chemical, biological, and physical data of water bodies as well as modeling to predict the water quality at design conditions. Professional judgement, based on wastewater sources and land uses, is also incorporated into the program. A record of each assessment, along with a water quality assessment summary, is completed for each activity. These summaries are added to the department's Assessment Data Base and are used for the basinwide assessment of water quality and the preparation of the biennial 305(b) report required by the Federal Clean Water Act. The 1993 305(b) update shows that just over 956 stream miles are impacted by chemical contaminants in the Susquehanna River basin. Of these, nearly 894 miles (93.5 percent) are affected by metals draining from abandoned mines, a major problem in portions of the North Branch Susquehanna River and the upper West Branch Susquehanna River. About 54 miles are affected by toxics from other sources.

The department uses State Water Plan Subbasin Areas as a geographic basis to report its assessments. The subbasins within the Susquehanna River basin along with a summary of the toxics problems in each follow:

*Subbasin 4 - Upper Susquehanna River*

Only 17.5 stream miles are impacted by toxics. Of these, 11.6 miles are degraded by heavy metals from acid mine drainage. The remaining problems are small with each affecting less than three stream miles.

*Subbasin 5 - Upper Central Susquehanna River*

All 111.7 stream miles reported as degraded due to toxics are impacted by metals from abandoned mine drainage. The biggest problems are on Catawissa Creek (41.5 miles), the Susquehanna River (28 miles), and Black Creek (25.5 miles).

*Subbasin 6 - Lower Central Susquehanna River*

Approximately 162.8 miles are adversely affected by metals draining from abandoned mines. The major problems are on Mahanoy Creek (52.2 miles), Shamokin Creek (34.7 miles), and Wisconisco Creek (16.7 miles).

*Subbasin 7 - Lower Susquehanna River*

Toxics problems affect 62.4 stream miles. Metals from abandoned mine drainage impact 39.8 miles primarily in the upper Swatara Creek basin. The other 22.6 miles are relatively small segments (8 miles or less) impacted by various sources: two segments are impacted by contamination at Texas Eastern compressor station sites, two are impacted by metals mobilized by acid rain, two are impacted by volatile organic compounds, one (Codus Creek) reflects a fish consumption advisory for dioxin, and one (Susquehanna River) has elevated levels of heavy metals.

*Subbasin 8 - Upper West Branch Susquehanna River*

All but 8.1 miles of the 377.2 stream miles impacted by toxics are due to metals draining from abandoned mines. Past mining has resulted in many problems in the headwater areas of the West Branch and some of its tributaries. Metals from active mining are listed as the source of the remaining problems.

*Subbasin 9 - Central West Branch Susquehanna River*

A total of 177.4 stream miles has been impacted by toxics. Of these, 155.6 are affected by metals from acid mine drainage. The major degradation is on the West Branch (50.6 miles), the Beech Creek basin (26 miles), Babb Creek (14 miles), and the Cooks Run basin (10.1 miles). Approximately 15.2 miles of Spring Creek have been contaminated by Mirex, which caused the Pennsylvania Fish and Boat Commission to ban fishing. In addition, five miles on Kettle Creek appear to be impacted by metals that come from the operation of a dam.

*Subbasin 10 - Lower West Branch Susquehanna River*

All of the reported toxics impacts (18.8 miles) are the result of drainage from abandoned mines. The most severe problem is on Loyalsock Creek (13.4 miles).

*Subbasin 11 - Upper Juniata River*

Toxics problems impact 26.9 stream miles, of which 24.3 miles are affected by metals from acid mine drainage. The largest impact is on Sugar Run (6.3 miles). The other problems (2.6 miles total) are related to a Texas Eastern compressor station site and a paper mill.

*Subbasin 12 - Lower Juniata River*

Toxics impacts total 1.4 miles. One problem (0.8 miles) is related to a Texas Eastern compressor station site and the other (0.6 miles) is due to volatile organic compounds.

## **Point Source Programs**

### ***NPDES PROGRAM***

Pennsylvania is an NPDES-delegated state and carries out NPDES permitting, compliance, and enforcement programs in accordance with state and federal regulations and the memorandum of agreement between the Department of Environmental Resources and the EPA.

Toxics control and management have been a major portion of the state's NPDES program since the early 1980s and are implemented pursuant to the Bureau of Water Quality Management's Toxics Management Strategy. The Toxics Management Strategy is the basis for writing NPDES permits for all point sources including the 304(l) discharges. A brief summary of the Toxics Management Strategy and toxics evaluation procedures is outlined below.

### ***STORMWATER MANAGEMENT PROGRAM***

Pennsylvania is implementing the federal stormwater permitting regulations (40 CFR 122.26) for stormwater discharges associated with industrial activities under the point source program. In Pennsylvania, two stormwater general permits have been issued--one for industrial activities and the other for construction activities. The Water Quality Management Program handles permits for stormwater discharges from industrial activities; the Land and Water Conservation Program handles permits for stormwater discharges from construction activities through county conservation districts as part of the Department's erosion and sedimentation control program. The majority of the discharges are expected to be managed through these general permits. However, individual permits are required for certain activities: discharges to streams designated as "special protection" under the anti-degradation program; SARA Title III facilities that exceed the reportable quantities for listed chemicals; and stormwater discharges containing or expected to contain toxic chemicals.

Pennsylvania has not established a specific toxic chemical control strategy for the Chesapeake Bay basin. The department addresses these substances statewide through several regulatory and

administrative programs which are discussed below. These programs are used in the development of Individual Control Strategies and for other NPDES permitting actions in the Bay basin.

The department has initiated a Watershed Permitting Process to manage permitting and other point source control actions, pursuant to sections 304(l) and 303(d) of the Clean Water Act. A Total Maximum Daily Load/Waste Load Allocation screening of point sources is conducted to identify chemical contaminant parameters of concern and the scope of field data collection needs. Based on these screenings, water body surveys are conducted for the substances of concern. This information is used to perform a detailed analysis and water quality-based multiple discharge waste load allocation. The waste load allocations are then translated into effluent limitations for NPDES permits.

The Federal Clean Water Act controls toxic pollutants by mandating that "...it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited...." The control of toxics is also mandated by the Pennsylvania Clean Streams Law in which pollution is defined as "...contamination of any waters of the Commonwealth such as will create or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to public health, safety, or welfare to domestic, municipal commercial, industrial, agricultural, recreational, or other legitimate beneficial uses..."

### **Toxics Control and Management Strategy**

Pennsylvania Code 93.7(f) and Pennsylvania Chapter 16 form the basis for the Bureau of Water Quality Management's Toxics Control and Management program. Chemicals are controlled and managed under the Water Quality Toxics Management Strategy developed pursuant to the above cited references. The Toxics Management Strategy is a water quality approach to control the discharge of priority pollutants and other chemicals. The Toxics Management Strategy uses a comprehensive step-by-step process for evaluating toxic pollutants and developing appropriate effluent limitations.

The steps in the application of the strategy are:

- Step 1: Conduct a preliminary review
- Step 2: Determine pollutants of further interest
- Step 3: Develop water-quality based limits and selection of toxics to be limited in the permit
- Step 4: Establish NPDES permit terms and conditions for control of toxic pollutants.
- Step 5: Follow up evaluation after initial permit issuance.
- Step 6: Establish final permit requirements

A brief discussion of the actions required for each step follows.

#### **Step 1 - Conduct a Preliminary Review**

The purpose of this step is to become familiar with the facilities and the wastewater discharges for which the NPDES permit application has been submitted. This step resolves any discrepancies in the application data and focuses on initial pollutants of interest. Pertinent historical data are reviewed including the compliance status of the applicant.

#### **Step 2 - Determine Pollutants of Further Interest**

The purpose of this step is to compile a complete list of toxic pollutants of interest based on knowledge of actual or potential pollutant presence in the discharges under review. Pollutants of further interest would be identified by the following screening process:

1. Priority pollutants which have a best available technology requirement. If a pollutant is required to be regulated by an applicable best available technology guidelines for the industry, the best available technology limit or the corresponding water quality-based limit (whichever is more stringent), must be in the permit regardless the presence or absence of the pollutant.
2. Non-best available technology priority pollutants for which the discharger must sample and analyze. These pollutants will also be designated as pollutants of further interest pending evaluation of water quality-based limits in Step 3.
3. Other toxics identified by the applicant as present in the discharge. Several places on the industrial NPDES application form allow the applicant to indicate that certain toxic pollutants are expected in the discharge. When the applicant identifies such pollutants as routinely present in the discharge, they become pollutants of further interest.
4. Other toxics known or suspected to be present by the permit writer. Based upon the type of discharger and the toxic pollutants normally associated with the discharge, the permit writer can designate any other appropriate toxics as pollutants of further interest.

*Step 3 - Develop Water-Quality Based Effluent Limits and Selection of Toxics to be Addressed in the Permit*

The purpose of this step is to determine which toxic pollutants should be addressed in the NPDES permit and in what manner they should be addressed using criteria established in the Water Quality Toxics Management Strategy.

*Step 4 - Establish of NPDES Permit Terms and Conditions for Control of Toxic Pollutants*

The purpose of this step is to establish appropriate effluent limitations, monitoring and reporting requirements, and other special conditions to be incorporated into the NPDES permit, based on the results of steps 1 through 3. One of the special conditions in this step is the requirement to conduct a Toxics Reduction Evaluation. Toxics Reduction Evaluations are conducted when the water quality-based requirements may not be met with available technology. This evaluation allows the discharger to: (1) study the characteristics of its waste discharge; (2) verify the extent of the toxic pollutants associated with the wastewater; (3) determine sources of these toxic pollutants; and (4) recommend control and/or treatment technologies which may reduce or eliminate the toxic pollutants. The department has developed extensive guidelines for conducting Toxicity Reduction Evaluations.

Under the permit conditions, the department may grant an extension of time to achieve the water quality-based effluent limitations, provided the permittee meets all eligibility requirements contained in Sections 95.4 of the department's rules and regulations.

A third special condition contains procedures for the demonstration of alternative site-specific bioassay-based instream water quality criteria. When water quality-based effluent limitations for the pollutants listed in the permit have been developed for the protection of fish and aquatic life, the permittee may demonstrate alternative site-specific bioassay-based instream safe concentration values for these pollutants. These procedures must be carried out in accordance with the Rules and Regulations of the department contained in Sections 93.8(D-E).

A fourth condition is the incorporation of procedures for demonstrating alternative method detection limits. The permittee may request an opportunity to demonstrate alternative facility-specific



minimum detection limits to account for interfering factors associated with the wastewater in questions.

***Step 5 - Follow Up Evaluation After Initial Permit Issuance***

The purpose of this step is to evaluate information submitted by permittees in response to initial permit special conditions concerning water quality-based effluent limitations and other requirements for the management of toxic pollutants.

During Step 5, the department evaluates the information in Step 4 which may have been submitted by the permittees in response to permit requirements: toxics reduction evaluations, requests for time extensions, requests for alternative site specific bioassay-based effluent limitations, and requests for alternative method detection limit determinations.

***Step 6 - Establish Final Permit Requirements***

The purpose of this step is to evaluate the results of the follow-up evaluations discussed in Step 5 of the NPDES permit and the related enforcement documents. Based on review of the toxics reduction evaluation and any related demonstrations, the NPDES permit may be reopened and modified or revoked and reissued to reflect appropriate changes resulting from the above evaluations.

The current toxics management program in Pennsylvania is essentially a chemical-by-chemical approach; applicable water quality criteria are based on protection of the most sensitive use (i.e., aquatic life or human health).

***BIOMONITORING PROGRAM***

Pennsylvania's chemical-specific approach to limit toxics in wastewater discharges has taken precedence over the use of biomonitoring as a means of controlling effluent toxicity. In a limited number of cases, the department has included whole effluent toxicity testing requirements in NPDES permits. Although the department views biomonitoring as an important element of toxics management, the limited availability of staff resources has prevented its widespread use in the NPDES program. For those cases in which biomonitoring requirements have been imposed, EPA Region III staff have interpreted the test results with follow-up actions coordinated between the two agencies.

***PRETREATMENT PROGRAM***

Pennsylvania has not been delegated primacy for the pretreatment program. The Bureau of Water Quality Management is actively participating in the program in a number of ways. Any pretreatment problems that Pennsylvania identifies as a result of field or compliance review activities are referred to EPA for action. The following 43 facilities in the Chesapeake Bay Basin have or are required to have pretreatment programs in place:

Altoona City Authority (2 plants)  
Tyrone Borough Sewer Authority  
Bellefonte Borough  
Curwensville Municipal Authority  
Lock Haven City

Columbia Borough Authority  
Lancaster Area Sewer Authority  
Lancaster City Sewer Authority  
Lebanon City Authority  
Greater Hazelton Sewer Authority

Pine Creek Municipal Authority  
Berwick Municipal Authority  
Carlisle Borough Authority  
Hampden Township Sewer Authority (2 plants)  
Lower Allen Sewer Authority  
Shippensburg Borough Authority  
Derry Township Municipal Authority  
Harrisburg City Authority  
Chambersburg Borough Authority  
Huntingdon Borough Authority  
Lackawanna River Basin Authority (4 plants)  
Scranton City Sewer Authority  
Adamstown Borough Sewer Authority  
York City Sewer Authority

Lower Lackawanna Valley Sewer Authority  
Wyoming Valley Sanitary Authority  
Williamsport Sewer Authority (2 plants)  
Union Township Municipal Authority  
Danville Municipal Authority  
Milton Municipal Authority  
Shamokin-Coal Township Jt. Sewer Authority  
Sunbury City Municipal Authority  
Middleburg Municipal Authority  
Kelly Township Municipal Authority  
Hanover Area Municipal Authority  
Penn Township Sewer Authority  
Springettsbury Township Sewer Authority

In addition to consulting with EPA Region III on its implementation actions, the Department of Environmental Resources, in cooperation with the Water Pollution Control Association of Pennsylvania, has been sponsoring pretreatment forums around the state for pretreatment coordinators, treatment plant operators, and consultants. The department plans to hold these forums about every six months. Also, the department's Operator Outreach Training Program provides on-site pretreatment assistance to municipalities around the state. Formal delegation of the pretreatment program depends on the availability of adequate staff resources to implement a meaningful program.

## **Nonpoint Source Programs**

### ***PESTICIDE MANAGEMENT PROGRAM***

The 1987 amendments to the Pennsylvania Pesticide Control Act are implemented through a regulatory program. All commercial and public applicators must be licensed to apply any pesticides while private applicators, such as farmers, must only be licensed to apply restricted-use pesticides. Over 25,000 applicators are licensed under this program. To become licensed, an applicator must pass an examination that requires knowledge of pesticide use in conformance with the label. Once licensed, an applicator must follow label requirements and periodically update training or face license revocation.

Pennsylvania is actively promoting an integrated pest management program. The program encourages integrated pest management using mechanical, cultural, and chemical control measures in developing pest control strategies. The integrated pest management program is founded on an agreement between the Pennsylvania Department of Agriculture and Penn State University. Audio-visual presentations and technical handouts promote the program and its techniques and the results have received much media attention. Over \$1 million in integrated pest management research projects have been funded over the past four years. This research has resulted in successful measures for reducing or eliminating pesticide use on tomato and poinsettia crops and the establishment of a U.S. Department of Agriculture cost-share program to encourage the adoption of crop management services. By the end of 1992, an estimated 400,000 acres were under integrated pest management.

## ***STORM WATER MANAGEMENT PROGRAM***

The stormwater management program mandated by the Pennsylvania Storm Water Management Act is implemented by the Department of Environmental Resources' Bureau of Dams, Waterways and Wetlands. The act requires each county to prepare watershed stormwater management plans which consider the hydrologic effects of land use changes and nonpoint source pollution. The plans must identify water quality controls associated with nonpoint source pollution. Local municipalities implement standards and criteria through the adoption of codes and ordinances.

## **Hazardous Waste Management Programs**

### ***RCRA PROGRAM***

Residual and hazardous waste regulations, developed through Pennsylvania's RCRA program, focus on source reduction to prevent waste. In the waste management hierarchy, source reduction has the highest priority, followed by use and reclamation, treatment, and disposal. The hazardous and residual waste regulations require each generator to develop a source reduction strategy. The generator must specify what actions it will take to reduce waste, when the actions will be taken, and the amount of reduction expected. A Source Reduction Strategy Manual helps generators to comply with the requirements and achieve source reduction. The manual includes a discussion of the regulatory requirements, elements of a comprehensive source reduction program, reduction measurements, and source reduction opportunity assessments. The department is also developing a technical assistance program to help waste generators implement source reduction programs.

In the future, the department will be training its own staff to identify waste reduction opportunities during inspection and permitting activities. The department is also considering development of a strategy to target technical resources to those waste streams which may have management capacity shortfalls.

### ***SUPERFUND PROGRAM***

Pennsylvania plays an active role in the federal Superfund Program by cooperating with EPA at the 99 state sites on the National Priority List. In addition, the department is pursuing remediation at sites not on the federal list under the auspices of the State Hazardous Sites Cleanup Act enacted in 1988.

To date, eight sites in Pennsylvania have been addressed and removed from the EPA Superfund List--more than any other state. Cleanups by potentially responsible parties have also been started at 16 additional sites on the EPA list. Under the state's superfund program, responses have been completed at an additional 29 sites with ten more sites scheduled for remedial action.

## **Air Quality Control Programs**

The Pennsylvania Department of Environmental Resources requires the application of Best Available Technology to control air pollutants, including toxics, from new sources. In addition, specific policies already exist regarding acceptable levels of air toxics from municipal and hospital

waste incinerators. Permittees for these types of facilities, as well as for coke oven batteries, must perform an air toxics analysis as part of their requirements.

The department plans to implement all of the Clean Air Act requirements for the control of hazardous air pollutants (toxics) promulgated by EPA for both new and existing sources. When possible, pollution prevention requirements will be incorporated during development of the regulations.

## **Maryland**

There are numerous programs to protect people and the environment from potentially toxic chemicals in the environment. Most of these programs are founded in law and detailed in regulations. In the Chesapeake Bay region, there are also programs and policies derived from the formal agreements signed by Maryland's Governor.

This appendix summarizes the efforts of the Maryland Departments of the Environment and Agriculture to protect the public and the environment from potentially toxic chemicals, including descriptions of programs to control or reduce toxic emissions, and examples of the progress made by these programs.

### **Water Quality Standards Program**

Water quality standards form the basis of Maryland's water pollution control program. Standards provide a regulatory mechanism to restore, protect, and maintain "fishable and swimmable" waters by protecting public health and aquatic life (i.e., fish, shellfish and other aquatic communities). Maryland's water quality standards reflect the latest scientific knowledge of the effects of pollutants on human health and aquatic life as well as controlling the discharge of pollutants. High quality state waters are protected from degradation and waters already degraded are improved to provide for reasonable public use and increased survival and diversity of aquatic life.

Maryland has assigned specific uses to its state waters. Waters protected for recreational use and the preservation of balanced populations of fish and wildlife require stringent standards and a high degree of protection. Restrictive designations, such as shellfish harvesting waters, put and take trout waters, and natural trout population waters, impose additional restrictions, as does the potable (drinkable) waters designation. Other less restrictive uses, like industrial water supply, irrigation, and navigation, are also protected.

Water quality standards are a combination of the use designation and the corresponding water quality criteria, which may be general (narrative) or specific (numerical). Water quality standards establish regulations which prevent the deterioration of water quality and can also be enforced in the courts if necessary.

One of Maryland's general water quality criteria states that potentially toxic chemicals may not be present in waters at levels harmful to human, plant, or aquatic life. This narrative water quality criterion allows the state to limit the discharge of any substances which may cause toxicity through permits. Specific water quality criteria are numeric values for named substances. For example, the criterion for protection of salt water aquatic life from short term exposure to silver is 2.3 micrograms per liter (parts per billion).

The first water quality criteria for potentially toxic chemicals were adopted for aldrin, dieldrin, endrin, toxaphene, DDT, PCBs, and benzidine in 1980. In 1987, Maryland enacted a law severely limiting the use of boat anti-fouling paints containing tributyltin. The use and sale of these paints came under regulation. The Department of the Environment subsequently adopted water quality criteria for tributyltin in fresh and marine waters in 1989. The Department of the Environment also adopted regulations prohibiting the discharge of chlorine or its compounds to natural trout waters and requiring the dechlorination of any effluent treated with chlorine. The Department of the Environment also adopted water quality standards for 27 potentially toxic chemicals in April, 1990, in response to requirements of the 1987 Amendments to the Clean Water Act. On June 7, 1993, these regulations were modified to facilitate their implementation.

The Department of the Environment continually assesses the merit, adequacy, and efficacy of Maryland's water quality standards through specific actions to determine that either a need exists or identify a pollutant of particular concern. Additionally, there exists a federally mandated review of state water quality standards every three years.

## **Point Source Programs**

### ***NPDES PROGRAM***

Facilities which discharge wastewater must obtain discharge permits to insure that point source discharges to surface waters are in compliance with state water quality standards. The National Pollutant Discharge Elimination System (NPDES) is a federal program to regulate discharges nationwide. Maryland received approval in 1974 to administer the NPDES program through a state discharge permit program which resembles the federal program.

The goal of the Maryland NPDES permit program is to assure that the state's water quality standards are not violated as a result of a single discharge or a group of discharges to a specific water body. This goal is accomplished using both technology-based and water quality-based permit limits. These limits establish the quality of the discharge by setting maximum limits on the levels of specific constituents in the effluents, including potentially toxic chemicals.

The Department of the Environment is required by the NPDES program to investigate all discharges--only chemical contamination which is either very low or cannot be eliminated for practical and financial reasons is allowed. All NPDES permits must be renewed every five years. This provides the Department of the Environment with an opportunity to review the discharger's performance and to impose additional or more restrictive permit limits if necessary.

In 1974, when the Department of the Environment began issuing NPDES permits, the emphasis was on technology-based limits. Industries discharging to state waters were required to use the best available technology in treating their discharges. Municipal sewage treatment plants were required to employ secondary treatment technology. In the late 1980s, permits were issued with increasing emphasis on water quality-based limits which impose more stringent controls than technology-based limits. The 1990 adoption of regulations aimed at the control of toxic chemical discharges placed additional emphasis on the water quality-based approach. These regulations establish quantitative criteria for the protection of human health and aquatic life for 27 potentially toxic chemicals. Additional implementation requirements were added to these regulations in 1993. All new and renewed NPDES permits are now written to meet the toxic chemical discharge control requirements.

All industrial and municipal facilities with NPDES permits are systematically monitored to assure that the limits specified are not exceeded. Best management practices are also required by NPDES permits at certain sites for control of potentially toxic chemicals that may be transported by runoff.

### ***STORMWATER MANAGEMENT PROGRAM***

The Department of the Environment also implements stormwater management and sediment control programs. Erosion and sedimentation from areas undergoing urban land development may impair water quality. Pollutants and nutrients accumulate rapidly on paved impervious surfaces. They are then transported into water bodies with stormwater runoff. Large sediment influxes may carry levels of toxic chemicals which are potentially harmful to aquatic life.

The primary goals of the state's sediment control and stormwater management programs are to maintain the pre-development runoff characteristics after development and thus reduce stream channel erosion, local flooding, siltation, and sedimentation. Although most of the sediment and stormwater control practices are not directly related to the control of toxic chemicals, many provide indirect benefits. Reduction in sediment transport and excessive surface water runoff provides some control of soil-attached chemicals. Best management practices often contribute to the interception and confinement of toxic chemicals.

### ***PRETREATMENT PROGRAM***

Maryland's Pretreatment Program controls pollutants discharged by industrial users to publicly owned wastewater treatment plants. The national pretreatment program, which was established with the 1976 amendments to the Clean Water Act, sets the framework, responsibilities, and requirements for implementing and enforcing pretreatment standards. Maryland received full delegation of pretreatment authority from EPA in September 1985.

Local governments have primary responsibility for pretreatment program implementation. Pretreatment programs are required for all wastewater treatment plants with a capacity of five million gallons per day or more and for smaller plants with significant industrial dischargers. There are currently 17 approved local pretreatment programs in Maryland. The Department of the Environment oversees the implementation of these programs for compliance with the Department's requirements and takes enforcement action where necessary. As amendments are made to the federal pretreatment regulations, Maryland adjusts its state program to incorporate all such modifications.

Progress made by the Pretreatment Program can be demonstrated using two of Maryland's largest facilities. The Back River and Patapsco River wastewater treatment plants are the municipal facilities which handle waste water for the Baltimore metropolitan area. Since the implementation of the pretreatment program in 1983, discharges of chromium, copper, cyanide, nickel, and zinc have been substantially reduced.

### ***BIOMONITORING PROGRAM***

All industries and municipalities are required to conduct biological effluent monitoring or biomonitoring if the potential for toxicity in their surface water discharges exists. Biomonitoring is used to test for the occurrence of toxicity as a result of unexpected interactions of chemicals present

in the effluent. Biomonitoring refers to laboratory testing of wastewater effluent for toxicity using biological organisms, such as fish and crustaceans. Short-term laboratory exposures (i.e., 48 hours) of organisms to full strength and diluted effluent provide an estimate of the effluent's acute toxicity through the observation of the deaths or abnormal behavior of the test organisms. Longer laboratory exposures (i.e., 7 days) provide estimates of effluent chronic toxicity through the observation of more subtle effects such as impairment in the test organisms' growth or reproduction.

Maryland has implemented a two-pronged program for the biomonitoring of wastewater effluents. All major and some minor wastewater treatment facilities are required to provide data from acute and chronic bioassay tests on the effluent. The type and frequency of the testing is determined by discharge flow, receiving water flow, and the potential to cause a toxic impact. These monitoring requirements are designed to identify possible contributors of acutely or chronically toxic materials to Maryland surface waters. Whenever biomonitoring reveals an effluent with acute or chronic toxicity, confirmatory testing and a toxicity reduction program to eliminate effluent toxicity is required of the responsible industry or municipality.

The second part of the biomonitoring program is the use of the Department of the Environment's Biomonitoring Laboratory to independently test effluents from selected facilities. The benefits of the independent laboratory tests include the identification of toxic effluents, potential violations of water quality standards, and the verification of biotoxicity testing results submitted by dischargers to meet their NPDES permit requirements. Since 1986, an increasing number of facilities have been tested in this manner--the vast majority show no toxicity. The few in which toxicity has been found have either eliminated the cause of toxicity or are in the process of doing so.

By 1990, all major industrial facilities had been assessed; 15 dischargers were found to have some toxicity in their discharge. Since that time, only six still have evidence of toxicity in their discharge. Of all municipal wastewater discharges evaluated to date, more than 95 percent have shown no evidence of toxicity in their effluents.

### ***CHEMICAL MONITORING PROGRAM***

Concentrations of chemical contaminants in effluents from municipal wastewater treatment plants and industrial processes are also monitored. This monitoring assures that the discharger does not exceed the limits of potentially toxic chemicals specified in their discharge permit. Dischargers are required to perform and report chemical monitoring of their effluent on a monthly basis. In addition, the Department of the Environment preforms random chemical-specific testing of effluents.

## **Nonpoint Source Programs**

### ***PESTICIDE MANAGEMENT PROGRAM***

The Maryland Department of Agriculture is responsible for regulating the use, sale, storage, and disposal of pesticides. The primary functions of the pesticide management program are to enforce state and federal pesticide use laws and regulations, ensure that pesticides are applied properly by competent individuals, and protect the health of citizens and natural resources. These functions are carried out through five major programs:

- pesticide applicator certification and training;
- pesticide use inspection and enforcement;
- pesticide technical information collection and dissemination;
- groundwater, worker, and endangered species protection; and
- special programs.

The Department of Agriculture certifies private and commercial users of pesticides through written certification examinations and mandatory annual update training to verify the competence of personnel applying pesticides. The department licenses and issues permits to businesses and public agencies that apply general or restricted use pesticides as well as pest control consultants that recommend pesticides or identify pests. Under the enforcement program, the Department of Agriculture conducts routine inspections of licensed pesticide businesses, public agencies, and restricted use pesticide dealers. Pesticide misuse and consumer complaints are also investigated. Pesticide information (use and regulations) is provided to pesticide applicators, dealers, federal and state agencies, and the general public. Pesticide usage surveys have been conducted since 1982 on a three-year interval to obtain information on use from farmers and private and commercial applicators.

The Department of Agriculture is developing a state management plan for agricultural pesticides and has implemented an Atrazine Best Management Practices Program to protect groundwater and surface water resources. Implementation plans for worker protection and endangered species protection programs have also been developed.

Special programs conducted by the department include an integrated pest management program for schools, an empty pesticide container recycling program, a pilot disposal program for unusable pesticides, and a well water monitoring program for farmers.

## **Hazardous Waste Management Programs**

Since the National Environmental Protection Act in 1969, there have been numerous laws passed to reduce potentially toxic materials in the environment. Most of them, including the Clean Water and Clean Air Acts, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, and the Superfund Amendments and Reauthorization Act of 1986, have resulted in regulatory systems that have served very effectively to reduce releases of potentially toxic chemicals into the environment, help scientists and managers understand where those releases occur, and list the chemicals that are involved.

In many cases, Maryland has received delegated authority to write state regulations within the guidelines of federal regulations. Some of the progress that has been made under these programs is presented below.

### ***OIL CONTROL PROGRAM***

The Oil Control Program regulates the aboveground and underground storage and transfer of petroleum products to prevent oil pollution. The underground storage tank program is based on the federal program adopted under Subtitle I of RCRA. The aboveground storage tank program has



established management requirements for the storage and handling of petroleum products to prevent releases of petroleum into the environment.

In 1988 the EPA passed regulations requiring the upgrade or replacement of underground storage tanks to meet certain technical standards, which were adopted by Maryland in 1991. These standards (early release detection, corrosion protection, and overfill/spill prevention) are designed to prevent releases from underground storage tanks. The new design features of underground storage tanks will prevent tanks from leaking in the future.

The aboveground storage tank program requires tanks to have secondary containment to collect any spills that may. The size of the containment must be equal to the greatest tank volume. The dike is constructed of an impermeable material and designed to prevent the petroleum from escaping into the environment. Additional requirements include proper venting and other related safety issues.

In the future, the Oil Control Program will continue to oversee the implementation of the underground storage tank requirements to meet the 1998 compliance deadline. Also, inspections of underground storage tanks will increase to determine if the owners are complying with the early release detection monitoring. This will prevent future leaks and, if they occur they will be detected at an early stage.

Another goal of the Oil Control Program is to remediate sites that have been previously contaminated with petroleum products. Currently, the program oversees more than 950 responsible party cleanups where some type of monitoring or remediation is occurring on a site that was previously contaminated with a petroleum product. The objectives of remedial actions are to close the source of contamination immediately, install treatment systems to prevent the further movement of oil into the environment, and restore the quality of the water to its natural state.

## **Air Quality Control Programs**

The Clean Air Act regulations promulgated by the Department of the Environment's Air and Radiation Management Administration, Maryland's Air Toxics Control and Mobile Sources Toxic Reduction Programs, and the Urban Air Toxics Initiative have greatly increased the number of facilities which must control air pollutant emissions. These regulations and programs have: decreased the emissions of criteria pollutants such as sulfur and nitrogen oxides, carbon monoxide, and volatile organic compounds; decreased ambient air borne lead dramatically; and provided for significant decreases in emissions of toxic chemicals from mobile sources. Projections are for continued decreases in all of these areas except lead, which has reached background levels.

The Air and Radiation Management Administration has been implementing programs that reduce air releases of potentially toxic chemicals since the 1970's. Many of these reductions were achieved by regulating chemicals called "criteria pollutants" for which a National Ambient Air Quality Standard has been established. These pollutants were regulated primarily to insure that ambient exposures do not result in concentrations that are toxic or "unhealthful" to people when they are inhaled.

## ***AIR TOXICS CONTROL PROGRAM***

In 1988, the Department of the Environment adopted groundbreaking air toxics regulations. These regulations have established Maryland as a leader in the area of air toxics control. Maryland's program, which was one of the first comprehensive state regulatory initiatives to be adopted, is considered by many to be one of the premiere air management programs in the country.

The regulations, covering over 600 pollutants, apply to small and large stationary sources. Sources covered by this regulation include very large operations like a steelmaking or chemical manufacturing plant to sources as well as a neighborhood drycleaner. As more facilities have been required to control emissions, total emissions of toxic chemicals have decreased.

The long-term goal of the program is to eliminate, to the extent practical, all toxic chemical releases from stationary sources required to have an air quality permit. This policy, which is embodied in the regulations' best available control technology provision, requires that any new equipment at a new or existing plant minimize toxic emissions by using best available control technology and pollution prevention practices. The regulation also insures that any residual emissions do not cause toxic effects.

There were two critical dates contained in the regulation. By July 1, 1990, sources were required to demonstrate that their emissions of carcinogenic and highly toxic chemicals would not unreasonably endanger public health. This requirement resulted in emission reductions of approximately 80 percent between 1988 and 1990.

Sources were also required to demonstrate that their emissions of a second group of pollutants composed of less toxic chemicals would not unreasonably endanger public health. This demonstration had to be made by January 1, 1992. Because these materials are less toxic, a smaller percentage reduction was achieved. The actual reduction is currently being quantified.

Between 1990 and 1992 the Department of the Environment entered into 18 consent orders with sources that could not comply with the two compliance dates. At this time, almost all of these orders are complete.

## ***MOBILE SOURCE TOXICS REDUCTIONS***

There have been significant reductions in the release of toxic chemicals from mobile sources such as automobiles and trucks. These reductions have resulted from technology advances generally, as well as cleaner fuels (generally efforts to reduce the release of pollutants that form ozone). The Air Lead Program, has essentially eliminated lead, a pollutant of extreme toxicity, from the exhaust of mobile sources and the air.

The Clean Air Act Amendments of 1990 established additional requirements to reduce mobile source emissions of toxic chemicals. Specifically, the new rules require cars to be built with cleaner emissions which will drastically reduce mobile sources of air pollution. Additional reductions will be generated from a variety of new programs that require gasoline to be reformulated to reduce emissions of ozone forming materials and specific toxic chemicals.

## ***URBAN AIR TOXICS INITIATIVE***

The Department of the Environment has been leading a national effort to improve the determination of the need for additional regulatory programs to address the complex mixture of potentially toxic chemicals found in the air of all urban environments. This initiative began in 1985 as part of an EPA sponsored Integrated Environmental Management Project. In 1989, the Department hosted a highly successful national workshop on urban air toxins.

As part of the Clean Air Act Amendments of 1990, the EPA is required to study and evaluate urban area sources and reduce potential cancer risk from these sources by 75 percent. Because of its experience with controlling air toxics, the Department of the Environment has been awarded a \$500,000 grant to assist EPA with this effort. A final report to EPA is to be completed in the fall of 1994. The Department, however, will be using the interim results of the study in developing and implementing "co-control" strategies to reduce toxic releases and ozone forming emissions. The Clean Air Act requires Maryland to submit a major ozone plan by November, 1994.

## ***AIR TOXICS MONITORING PROGRAM***

The Department's Air and Radiation Management Administration began its current monitoring program for toxics in 1990; less sophisticated toxics monitoring for metals began in the 1950s. In 1990, the Air and Radiation Management Administration started sampling for 41 toxic chemicals around Baltimore City. Additional sites at three other locations have been added since the program's inception. The site locations change each year, so that nearly a dozen locations have been sampled for at least one season.

In addition, the Air and Radiation Management Administration will begin sampling for a comprehensive list of volatile organic compounds as part of the national Photochemical Assessment Monitoring Stations network. This effort will include sampling for some priority toxic chemicals.

Metals have been sampled since the mid-1950s by the Air and Radiation Management Administration and its predecessors. Iron, manganese, nickel, cadmium, chromium, arsenic and lead have all been sampled at some period all across the state. The sampling for the other metals was discontinued several years ago as most concentrations were below the level of detection or at only background levels. Only lead is still sampled.

Concentrations of three of the more common carcinogens found in the air of all urban areas (1,3-butadiene, benzene, and chloroform) are sampled at a downtown Baltimore site. Benzene and butadiene are released primarily from mobile sources. Chloroform is an industrial as well as mobile source pollutant. Mean concentrations of benzene are about 1.3 parts per billion and of butadiene about 0.32 parts per billion while chloroform mean concentrations are less than 0.2 parts per billion indicating that most of the volatile organic compounds are from cars and trucks (mobile sources) rather than industrial sources. Concentrations of both benzene and butadiene appear to be decreasing.

## **Toxics Release Inventory Trends**

The Toxics Release Inventory of the Department of the Environment's Hazardous and Solid Waste Management Administration shows a decrease of 46 percent from 1988 to 1991, for the combined

total of all releases to air, water, and land. The 83 percent decrease in direct releases to water was greater than observed decreases in releases to air or land. While not as dramatic as water, there has also been a steady decrease in reported air releases of 37 per cent since 1988. Land releases have decreased by 28 percent over the same time period. Decreasing trends are expected to continue due, in part, to implementation of more stringent regulations, but also to voluntary pollution prevention and source reduction activities in which many facilities are now engaging.

## **Pollution Prevention Program**

Over the past two years, the Department of the Environment has received \$350,000 from EPA to fund a multimedia pollution prevention initiative. Current projects include collaborating with other state agencies to:

- investigate the capital needs of small business for pollution prevention implementation;
- develop industry-specific technical assistance;
- design and present a series of pollution prevention seminars; and
- create and present a multimedia technical cross-training curriculum for Department staff.

## **Environmental Monitoring Programs**

The Department of the Environment's Water Management Administration has several monitoring programs to evaluate the impact of pollution in Maryland's surface waters. These programs look for indications of impacts caused by changes in ecological communities and measure the accumulation of chemical contaminants in fish and shellfish tissue.

### ***FISH TISSUE MONITORING PROGRAM***

Since the early 1970s, the chemical contaminant levels in fish found in Maryland waters have been monitored. In 1977, a statewide fish tissue monitoring network was established in the Maryland portions of the Chesapeake Bay and its tributaries. While this monitoring program did not originally focus specifically on the safety of fish for consumption, it was modified in 1989 to address this concern. Currently, the monitoring program divides state waters into three groups: western Maryland watersheds, Chesapeake Bay watersheds, and Baltimore/Washington urban watersheds.

Samples from each of these areas are collected every three years. Collections consist of two samples of accumulator species and one sample of game species. Of the accumulator samples, one includes whole fish, while the second includes only fillet tissue. Of the game species, only the fillet portion is analyzed. This allows water-quality managers to evaluate the relative levels of chemical contaminants of concern accumulating in state waters, and contaminant levels in the fish to determine safety for human consumption.

Follow-up tissue surveys have also documented declines in chemical levels. For example, arsenic and chlordane in striped bass from the lower Potomac have exhibited substantial declines for the period 1986 to 1991. Lead and cadmium data from surveys of blue crab tissue in 1983 and 1990 indicate decreasing concentrations in all tributaries evaluated.

With the exception of chlordane levels in Baltimore Harbor, Back River, and Lake Roland, current contaminant levels in tissue are below those recognized as harmful to human health. Fish consumption advisories, recommending that consumption of bottom feeding species be limited, have been issued for these affected waterbodies. In those waters where follow-up data have been collected, levels of the chemical contaminants identified in these advisories are declining.

The Water Management Administration also periodically conducts intensive surveys of contaminant levels in the edible portion (fillet) of both resident and migratory species in the Chesapeake Bay and its tributaries. The species surveyed have included white perch, spot, channel catfish, brown bullhead, American eel, bluefish, striped bass, and blue crab.

### ***SHELLFISH TISSUE MONITORING PROGRAM***

Since the 1960s, the Department of the Environment has been surveying metal and pesticide levels in oysters and clams from the Chesapeake Bay and its tributaries. From the 1970s through 1987, samples were collected annually or biannually. In response to low levels of contaminants and negligible yearly changes in those levels, this baywide sampling is now performed once every three years, with the off years being devoted to analysis of results and intensive small-scale shellstock surveys. This comprehensive data record for metals and some pesticides in shellfish tissue provides information regarding long term trends in levels of toxic substances in Maryland estuaries.

Shellfish monitoring data indicate dramatic declines in tissue concentrations of arsenic, cadmium, copper, mercury and zinc from 1974 through 1990 (the most recent year for which data are available). The 1990 data also show that, for the first year since monitoring began in the early 1970s, the insecticide chlordane, removed from the market in April 1988, was not detected in oyster tissue.

### ***PESTICIDES MONITORING PROGRAM***

As part of new initiatives under the 1989 Chesapeake Bay Basin Toxics Reduction Strategy, the Department of the Environment has implemented two special projects to assess levels of potentially toxic chemicals and their effect in Maryland surface waters.

In 1992, the Department of the Environment performed seasonal monitoring of selected Maryland waters for high-usage and high-profile pesticides. Waters were selected adjacent to agricultural lands to assess the potential contribution of agricultural pesticide usage to Maryland surface waters. Preliminary results of this project indicate that only a few pesticides were detected, primarily during periods of application. No pesticides were detected at levels exceeding relevant criteria.

In 1992, the Department of the Environment performed a preliminary survey of pesticide usage in several neighborhoods of the Baltimore metropolitan area and of residential pesticide levels in selected Baltimore streams. A seasonal stream monitoring project is planned in 1994 to assess the potential contribution of residential pesticide usage to urban streams.

### ***SEDIMENT CONTAMINANT MONITORING PROGRAM***

Most chemical contaminants released to water are found in very low concentrations in the water because most substances adsorb to particles and settle to the bottom. For this reason, sediments provide some indication of where water pollution has occurred and a relative indication of its concentration.

Determination of concentrations of potentially toxic chemicals in bottom sediments is not currently required by any regulatory program. Nor do applicable state or federal regulatory criteria exist for determining “acceptable” concentrations of any contaminant, although EPA is currently drafting sediment quality criteria. The Department of the Environment’s Chesapeake Bay and Watershed Management Administration currently monitors 46 sites in Maryland tributaries annually and 22 stations in Maryland’s mainstem intermittently. The sediment is analyzed for metals and for organic chemical contaminants.

Baltimore Harbor is a major urban and industrial area that has been subject to contamination from industrial and municipal effluents, nonpoint source runoff, and atmospheric deposition. A comparison of historical and current monitoring data shows that in general, sediment contaminant concentrations are decreasing in both the Chesapeake Bay mainstem and Baltimore Harbor. The mainstem of Chesapeake Bay is subject to the same sources, but at a much greater distance, with more chance for dilution, yet decreases in sediment concentrations are present in the mainstem as well. This is due, in large part, to substantial declines since the mid-1970s in the discharge of metals. One of the driving forces for these reductions has been the NPDES Program.

### ***BENTHIC COMMUNITY MONITORING PROGRAM***

In the early 1970s, the Maryland Department of the Environment established a benthic monitoring program. It includes stations located in water bodies across the state which are sampled biennially. Evaluations of populations of benthic or bottom dwelling organisms provide assessments of overall water quality conditions. Stations are specifically selected to monitor water quality changes upstream and downstream of major discharges, around metropolitan areas, and suspected nonpoint pollution sources, or to document conditions in relatively unaffected or pristine streams. Intensive, site-specific benthic investigations are made to evaluate the possible impacts of specific discharges on water quality and stream biota.

## **District of Columbia**

### **Water Quality Standards Program**

The District of Columbia promulgated an extensive list of water quality standards for toxics in its waters in 1985. More recently, the district revised its water quality standards for surface and ground waters. The water quality standards were published as proposed rules on September 7, 1990 and addressed at a public hearing on June 6, 1991. Due to a significant number of responses and comments from interested parties and the EPA on the proposed standards for surface waters, the groundwater standards were published separately as Proposed Rulemaking on April 2, 1993. This separation allowed the District of Columbia to incorporate comments from the public hearing and discussions between the District of Columbia government and other concerned agencies into the surface water standards.

The water quality standards for groundwater were promulgated as Final Rule on July 2, 1992 and the water quality standards for surface water were published as Proposed Rulemaking on April 2, 1993. The water quality standards were reviewed and approved for final rulemaking by the District of Columbia’s Corporation Counsel and the final set of standards adopted in March 1994.

Both chronic and acute criteria have been established for chemicals in the water quality standards. The chemicals include those for which EPA has published water quality criteria as well as several substances for which no EPA criteria exist.

Although the District of Columbia does not currently use groundwater sources for potable water supplies, the groundwater will be protected for beneficial uses including surface water recharge, drinking water in other jurisdictions, and potential future use as a raw drinking water source. The constituents and numerical criteria for groundwater are those established by the EPA for drinking water.

## **Point Source Program**

### ***PERMITTING PROGRAM***

The main point source discharge in the District of Columbia is the Blue Plains Wastewater Treatment Plant. Combined sewer overflows are also a point source of pollution. The District of Columbia's point source program strives to use the best and most cost-efficient technology for the treatment of municipal effluent and combined sewer overflow. Blue Plains Wastewater Treatment Plant, one of the largest treatment facilities in the country, provides primary, secondary, and tertiary treatment followed by chlorine disinfection and sulphur dioxide dechlorination to eliminate the toxic effects of residual chlorine.

The Blue Plains Wastewater Treatment Plant serves the District of Columbia as well as parts of Montgomery and Prince Georges counties in Maryland, parts of Fairfax County in Virginia, and several suburban federal facilities. The District of Columbia's share in the current full treatment design flow is 135 million gallons per day.

A study conducted on a sludge management plan for Blue Plains recommended a combination of composting (off-site) and incineration (on-site) as a long-term sludge disposal plan. The District of Columbia is unable to dispose of the 2,000 tons per day of sludge generated by Blue Plains and has relied on neighboring jurisdictions for sludge disposal on land. The District of Columbia has tried to obtain approval to incinerate the sludge, however, this request has been rejected by the EPA.

Presently, the EPA issues NPDES permits in the District of Columbia with review and comments from the District of Columbia government. Regulations were drafted to establish procedures which will allow the district to issue discharge permits for point sources within its jurisdiction. These regulations are expected to be finalized in 1994.

### ***PRETREATMENT PROGRAM***

The District of Columbia Department of Public Works, Water and Sewer Utility Administration manages the pretreatment of industrial waste discharged into the sewer system and Blue Plains. The district promulgated pretreatment regulations in 1986 and last amended them in 1990. Under these pretreatment regulations, the District of Columbia has issued 42 discharge permits to control heavy metals and toxics emanating from industrial dischargers and entering the sanitary sewer. The District of Columbia has also issued 56 Temporary Discharge Authorizations to individual companies, mostly for groundwater remediation.

## ***COMBINED SEWER OVERFLOW ABATEMENT PROGRAM***

The District of Columbia, like other metropolitan cities, has faced combined sewer overflow problem for several decades. The major areas of concern are: aesthetic degradation due to the discharge of combined sewer overflow debris; frequent fish kills due to severe dissolved oxygen depletion; and restriction of water contact recreation due to fecal coliform contamination.

O'Brien and Gere conducted a detailed feasibility study to reduce the combined sewer overflow problem in the District of Columbia in 1983. Several alternatives were considered and the most cost-effective recommendations included:

1. Increase the storage capacity of the trunk sewers by providing dynamically controlled fabridams at nine of the largest overflows and increase the weir heights of overflow structures at 54 sites;
2. Increase the capacities of pumping stations to avoid overflow to the river;
3. Complete the separation of several partially separated drainage areas;
4. Reduce biological oxygen demand, solids that settle, and fecal coliform levels in the Anacostia River by constructing three swirl treatment facilities;
5. Construct a screening facility at Piney Branch; and
6. Include a separation process at the main Anacostia interceptor.

The District of Columbia's Combined Sewer Overflow Abatement Program includes all of the above recommendations. The program is expected to cost \$70.6 million. Phase 1, which includes recommendations 1 and 2, has been completed.

A major swirl facility has been constructed at North East Boundary near Robert F. Kennedy Stadium with a treatment capacity of 400 million gallons per day. Before construction of the other two facilities, the performance of the facility was reviewed. The evaluation revealed significantly reduced fecal coliform bacteria levels in the facility's effluent. In November 1991, the Metropolitan Washington Council of Governments performed a study of the water quality benefits of the Combined Sewer Overflow Abatement project in the tidal Anacostia River. The study found that fecal coliform bacteria levels in the Anacostia River, both upstream and in the combined sewer overflow impacted zones, were significantly reduced. The water quality in the District of Columbia should continue to improve with completion of all O'Brien and Gere recommendations.

Although the plan does not specifically address toxics in combined sewer overflows, the District of Columbia is reevaluating the combined sewer overflow problem and determining options for chemical control. As part of this study, the toxics in the combined sewer overflows will be identified. Depending upon the results, a program to control toxics in combined sewer overflows may be developed.

## **Nonpoint Source Programs**

Nonpoint source pollution within the District of Columbia has a significant impact on the receiving waters. Therefore, the District of Columbia government is committed to develop mechanisms to prevent and control nonpoint source problems. In response to the Section 319(h) of the Clean Water



Act requirements, the District of Columbia prepared a Nonpoint Source Management Plan in 1989 and submitted it to the EPA. This document provides a statewide strategy for controlling nonpoint source pollution and describes present and planned nonpoint source pollution abatement projects. A Nonpoint Source Management Program by the District of Columbia, using Clean Water Act Section 319(h) funds, resulted from this plan.

The main goal of the District of Columbia's Nonpoint Source Management Program is to reduce nonpoint source pollution to improve water quality. Approximately, 65 percent of the District of Columbia's surface area is impervious, therefore, the Nonpoint Source Management Program targets urban runoff. Surface runoff carries sediment, heavy metals, road salts, oil and grease, and other contaminants to the receiving waters.

The Nonpoint Source Management Program establishes a system to coordinate these activities, ensuring that the limited funds are used efficiently. It also ensures that certain aspects of nonpoint source prevention and control are addressed and that high-priority water bodies are targeted.

The four goals of the Nonpoint Source Management Program are as follows:

1. Coordinate nonpoint source activities and other nonpoint source activities among state, regional, and federal agencies involved in nonpoint source pollution prevention and control.
2. Inform and educate city residents about nonpoint source pollution prevention and control, particularly in nutrient management.
3. Facilitate technology transfer, particularly for those technologies that prevent and control urban runoff.
4. Update the District of Columbia Nonpoint Source Assessment Report and Management Plan to incorporate information gained from nonpoint source monitoring efforts and successful nonpoint source control strategies. The plan should also reflect new prevention and control strategies within the District of Columbia.

The District of Columbia's Nonpoint Source Management Program has identified several sites for implementing projects that would demonstrate new urban nonpoint source control technologies. The program is sponsoring a demonstration project at Anacostia Park within the Anacostia River watershed. The District of Columbia, in both its nonpoint source assessment and Nonpoint Source Management Plan, has targeted this watershed for nonpoint source control actions to help improve the water quality of the Anacostia River.

The demonstration project will have a sand filter stormwater management structure under a parking lot serving the park. Presently, the District of Columbia recommends this type of structure to developers applying for a stormwater permit. The structure allows for moderate detention and oil separation; it also has built-in infiltration to separate suspended matter from stormwater runoff that would otherwise be discharged directly to surface waters. The structure also protects groundwater from possible contamination because it is a self-contained structure. The Nonpoint Source Management Program has requested additional Section 319(h) funds to monitor the efficiency of this facility and provide maintenance.

## ***STORMWATER MANAGEMENT PROGRAM***

The goal of the District of Columbia's Stormwater Management Program, established in 1984, is to control nonpoint source pollution by ensuring that developers control both the quantity and quality of stormwater runoff from project sites by using best management practices. The program reviews and approves all construction and grading plans submitted to the District of Columbia government for compliance with stormwater management regulations. Engineers also provide technical assistance to developers to select best management practices for a particular site. The District of Columbia's Government Civil Infraction Program enforces the regulations. Inspectors have the authority to issue citations, fines, and stop-orders to violators of stormwater management regulations.

## ***PESTICIDE MANAGEMENT PROGRAM***

The main objectives of the District of Columbia's Pesticide Management Program are to train and certify pesticide applicators in the proper labeling, distribution, disposal, storage, transportation, and safe use and handling of pesticides. Regulatory activities associated with this program are pursuant to the provisions in the Federal Insecticide, Fungicide, and Rodenticide Act, as amended. This program, initiated in 1978, is also responsible for the enforcement of the Pesticide Operation Act of 1977 and Supporting Regulations for the District of Columbia (DC Pesticides Operation Act and the DC Municipal Regulations, Title 20).

The District of Columbia will develop a plan for implementing the revised 40 CFR 171 regulations for certification and training after they have been finalized. The District of Columbia will compose its certification and training requirements with the revised federal requirements.

The District of Columbia's pesticides program has the following functions:

- To assure compliance with applicable legal requirements related to the distribution, sales, storage, production, transportation, use, application, and disposal of pesticides.
- To minimize the hazards of pesticide use to human health, fish and wildlife, and the environment, while assuring the continued availability of the chemicals necessary for their protection.
- To encourage non-chemical control methods, such as mechanical, cultural, and biological controls, to reduce the quantity of pesticides used in the District of Columbia.
- To implement civil penalties using Civil Infraction Tickets for those violations of the District of Columbia Pesticide Law that do not warrant criminal prosecution.

The District of Columbia's Lawn Care Initiatives include the following activities:

- Distribute EPA and District of Columbia information concerning compliance during lawn care use inspections. The District of Columbia will compile fact sheets addressing lawn care compliance issues such as licensing requirements, drift misuse, and supervision of application safety.
- Target non-agricultural use inspections of the lawn care industry and report to EPA Region III the number of lawn care inspections and enforcement actions.

- Continue to pursue tips and complaints concerning lawn care advertising violations discovered during inspections.

### ***INTEGRATED PEST MANAGEMENT***

The District of Columbia's Integrated Pest Management program began in 1992 with surveys targeted at two groups: organizations and businesses registered to apply pesticides in the District of Columbia and residential users of pesticides. To educate the public on the benefits of integrated pest management, the District of Columbia has produced and distributed two pamphlets and created a portable display for use at community functions.

### ***PUBLIC OUTREACH AND EDUCATIONAL ACTIVITIES***

To distribute useful information on District of Columbia and federal pesticide regulations, a quarterly "Regulatory Newsletter" will be published and sent to all pesticide operators licensed to do business in the District of Columbia. In addition, the District of Columbia will cooperate with other agencies to educate the public in the safe, legal, and effective use of pesticides through news releases, information bulletins, and community meetings.

The District of Columbia has developed a communication strategy in cooperation with industry groups and the University of the District of Columbia Cooperative Extension Service to distribute information to the public and the regulated community on the new Worker Protection Standards. The District of Columbia has been informing industry groups, the general public, and government agencies about the proposed worker standards.

The District of Columbia has worked with the University of the District of Columbia Cooperative Extension Service to develop a training and education program for greenhouse workers. The training program targets the safe use of pesticides and the responsibility of each person to protect themselves from misused or mishandled pesticides.

### ***GROUNDWATER CONTAMINATION PREVENTION***

Under the District of Columbia's pesticide program, a specific groundwater management plan is being developed. The main thrust will be directed toward the training of lawn care and exterior landscape pesticide applicators in the proper use of pesticides to prevent groundwater contamination. A final groundwater implementation plan to control pesticide contamination of groundwater will be submitted to the EPA Region III.

The District of Columbia meets several times a year with the University of the District of Columbia Cooperative Extension Service to discuss changes in the applicator training necessary to protect groundwater. The District of Columbia will specifically discuss Chesapeake Bay concerns as they relate to pesticide use and disposal. They will also continue to share information obtained from use-observation inspection monitoring with the Cooperative Extension Service and update training to include problem areas.

## ***PESTICIDE ENFORCEMENT POLICY***

The District of Columbia has developed an Enforcement Response Policy which utilizes an Enforcement Matrix, a Schedule of Fines, and a list of enforcement actions for each type of violation. Investigations will be initiated by the District of Columbia within 24 hours of from receipt of the complaint. The District of Columbia initiates enforcement actions within one to two weeks following completion of a case.

## **Surface Water Monitoring Program**

### ***WATER QUALITY MONITORING PROGRAM***

The goals of the District of Columbia's surface water quality monitoring program are to develop a reliable water quality data base and to assess long-term water quality in response to different management strategies. Traditionally, the program has focused on the Potomac River estuary and its tributaries. The federal Clean Water Act and the Chesapeake Bay Agreement have resulted in the need for additional water quality data, particularly toxics data. The District of Columbia determined where data deficiencies were and recommended, as a first step, a survey of sediments for chemical contaminants.

Water column samples for metals analysis are collected on a quarterly basis. Fish samples are collected on an annual basis for heavy metal and EPA Priority Pollutant analysis. The District of Columbia has also funded two surveys (1990 and 1992) to determine the extent and type of chemical contaminants in the sediment. The Interstate Commission on the Potomac River Basin was selected to conduct the two surveys. Both surveys were designed to determine the possible impact from point sources of pollution on the sediments. The results showed elevated levels of heavy metals at certain locations. In addition, the Water Quality Monitoring Program has submitted a proposal to the EPA Region III to monitor the impact of nonpoint source runoff on sediment quality. If approved, the monitoring data will help develop a more complete picture of the sources of toxic loadings to the District of Columbia's sediments.

The survey and analysis of sediments from the District of Columbia's waters confirmed the presence of a wide variety of organic chemicals (60 out of 100 Priority Pollutants). These chemicals were found at almost every location sampled. In most cases, however, the quantities detected were extremely small or close to background levels.

It was estimated that the total PCB concentrations at all stations were at levels of possible concern for meeting the EPA criteria of the one in a million, 70-year cancer risk level for humans. Chlordane levels were detected above the Food and Drug Administration's "action levels" at eight of the 28 locations sampled. Based on EPA guidelines for the Great Lakes, six metals from the Priority Pollutant list were typically at heavily polluted levels.

In a fish tissue survey conducted in 1989, catfish tissue analyses confirmed the presence of PCBs and chlordane in quantities at or above the Food and Drug Administration's action levels of 2.0 parts per million for PCBs and 0.3 parts per million for chlordane. On July 31, 1989 the District of

Columbia's Commissioner of Public Health issued a public health advisory on the consumption of channel catfish, carp, and eel caught within the city limits of the Potomac and Anacostia rivers. The advisory warned residents to limit their consumption of the affected species to one-half pound per week. This warning was necessary because various surveys conducted by the District of Columbia indicated that a significant portion of residents consume fish caught in the Anacostia or Potomac rivers.

## **Hazardous Waste Programs**

### ***HAZARDOUS WASTE MANAGEMENT PROGRAM***

The District of Columbia's Hazardous Waste Management Program, was developed to protect both human health and the environment from hazardous waste releases due to improper handling, transportation, storage, and disposal activities, pursuant to the District of Columbia Hazardous Waste Management Act of 1977, RCRA and their amendments. Disposal of hazardous waste is prohibited in the District of Columbia; wastes are transported out of the District of Columbia for disposal.

Program activities focusing on RCRA grant responsibilities which include program authorization and regulation development, permitting, program administration, waste minimization and pollution prevention, and compliance monitoring and enforcement.

In 1993, the District of Columbia drafted hazardous waste regulations in conformance with the requirement of the District of Columbia's Office of Documents for codification in the District of Columbia Municipal Regulations. The proposed regulations were forwarded to the District of Columbia Office of the Corporation Counsel for legal review.

To assist the regulated community in understanding the District of Columbia's Hazardous Waste Management Program, copies of the regulations, generator fact sheets, and copies of the Generator Handbook are distributed to new notifiers of regulated waste activity and generators. The District of Columbia also conducts generator workshops.

Site inspections are performed to determine whether generators, transporters, and storage facilities are complying with applicable regulations. These compliance evaluation inspections are performed in conformance with procedures contained in the RCRA Inspection Manual. (Selection criteria inspections schedules will include Bay impact).

The District of Columbia uses EPA's RCRA Implementation Plan-Flexibility Process to redirect resources available under EPA priorities which are not applicable to the District of Columbia. The EPA developed this process to allow jurisdictions to redirect resources intended to address national priorities toward local issues. This process will be used in the District of Columbia to identify non-notifiers of regulated waste, generators affected by the Toxicity Characteristics rule, and facilities that may impact the Chesapeake Bay.

The District of Columbia is in the process of issuing a hazardous waste questionnaire to identify violators and non-notifiers of regulated waste activity. The questionnaire will be mailed to businesses identified by the selected Standard Industrial Codes or the District of Columbia business category, as reported on business license applications to the District of Columbia Business Regulation Administration. (Selection Criteria will include Chesapeake Bay impact.)

The District of Columbia's Hazardous Waste Management Program is developing a civil enforcement policy based on the District of Columbia Hazardous Waste Regulations, the District of Columbia Compliance and Enforcement Strategy, and the EPA Enforcement Response Policy. The policy will describe an enforcement penalty matrix which will include the regulation cited, the severity and frequency of the violation, and the monetary penalty for first, second, and third offenses.

### ***WASTE MINIMIZATION AND POLLUTION PREVENTION PROGRAM***

A revised waste minimization and pollution prevention program is being developed to meet the 1993 Capacity Assurance Plan submittal requirements. This program endorses the national goals of pollution prevention and waste reduction. The technical assistance portion of this program will identify source reduction and recycling opportunities and promote the use of additional waste minimization methods through the distribution of fact sheets. It will also promote in-house waste reduction audits for specific industries.

Waste reduction in the RCRA program will be enhanced through revisions of inspection procedures and the development of waste minimization programs by generators. Designated facilities are required to develop specific pollution prevention programs by statute.

The District of Columbia is developing an integrated pollution prevention and waste minimization program in accordance with guidance received from the EPA. This program endorses the national goals of waste elimination and reduction. The Toxics Source Reduction and Business Assistance Act provides the initial statutory basis for implementing pollution prevention within the district.

The District of Columbia has received "Pollution Prevention Incentives for the States" funding from the EPA to educate and train District of Columbia employees on pollution prevention, produce pollution prevention workshops for the automotive service sector, and develop a district-wide Pollution Prevention Strategic Plan. It is anticipated these efforts will be facilitated by the Center for Hazardous Materials Research and will encourage participation from the private sector, the university community, and the Metropolitan Washington Council of Governments. An information resource center for pollution prevention and waste minimization is also planned. Future projects may include a district analog to the federal Source Reduction Review Project to incorporate pollution prevention into the rulemaking process.

Concurrently, the waste minimization component of the hazardous waste management program, funded by EPA Region III through RCRA, is being expanded to comply with increased emphasis from EPA to incorporate pollution prevention in the media programs. The waste reduction strategy will be detailed in the District of Columbia's RCRA 3011 workplan. This effort is also coordinated with and is in accordance with the waste reduction mandates in the Capacity Assurance guidance.

### ***UNDERGROUND STORAGE TANK PROGRAM***

The District of Columbia's Underground Storage Tank Program was established to prevent and control leaks and spills that may result from underground storage tanks and contaminate groundwater and subsurface soil. All non-residential underground storage tanks containing gasoline or hazardous materials must be registered, allowing the District of Columbia to record the location, contents, and condition of storage tanks. All newly installed underground storage tanks are required to be non-corrosive.

The Leaking Underground Storage Program was established to provide remediation efforts where releases occurred. The program has a trust fund to provide funding for remediation and to recover costs from the responsible parties (which are reimbursed to the trust fund).

In 1993, the District of Columbia amended the Underground Storage Tank Management Act. The amendment made several technical and clarifying modifications which improve the administration of the act and reduce the potential for litigation from enforcement actions.

## **Air Quality Control Program**

Air pollution control activities in the District of Columbia are authorized by the 1984 amendments to the District of Columbia's Air Pollution Control Act and the Federal Clean Air Act. Under the District of Columbia's air pollution control program, plans and programs are developed and implemented to protect and manage the District of Columbia's air resources. This program determines allowable source emissions, issues construction and operating permits, and inspects air pollution sources. This program also coordinates and inspects asbestos renovation and demolition, and operates and maintains a district-wide ambient air quality monitoring network.

The District of Columbia air pollution control programs will comply with Title III of the Clean Air Act--Maximum Available Control Technology Standards for chemicals--once EPA has finalized the standards.

# **Virginia Regulatory/Management Program Implementation Progress**

## **Water Quality Standards Program**

Instream water quality standards include both narrative statements which describe general water quality requirements and numeric limits for the specific physical, chemical, and biological characteristics of water. The statements and limits describe the water quality necessary for reasonable and beneficial uses such as swimming, the propagation and growth of aquatic life, and the domestic water supply. Generally, instream water quality standards are the maximum concentration allowed in the water before unacceptable adverse effects occur.

Past water quality standards focused on the protection of aquatic life with the exception of standards for public water supplies and groundwater. Recent emphasis has been placed on the establishment of water quality standards for the protection of human health, however, due to the 1987 amendments to the Clean Water Act. The Clean Water Act mandates the adoption of water quality standards for all toxic pollutants listed pursuant to Section 307(a) for which criteria have been published under Section 304(a) and the discharge or presence of which could reasonably be expected to interfere with designated uses adopted by the state.

Efforts to address chemicals in Virginia's waters date back to the Kepone contamination of the James River in 1976. The following water quality standards were adopted by the Virginia State Water

## Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

Control Board in response to identified toxic problems in the Chesapeake Bay area involving specific chemicals.

<u>Standard</u>	<u>Basis</u>
Kepone	Contamination of James River
Mercury	Contamination of South Fork Shenandoah River
Dioxin	Contamination of Jackson and James rivers
Chlorine	Toxicity to aquatic life
Tributyltin	Toxicity to aquatic life

Virginia's attempts to comply with the Clean Water Act's requirements to adopt water quality standards for toxic chemicals culminated with the adoption of new section VR 680-21-01.14 (Standards for Surface Water) to the standards on March 30, 1992. Included in this section were 41 numeric standards for the protection of aquatic life and 66 numeric standards for the protection of human health. This section also included definitions of acute and chronic toxicity, an allowance for using updated EPA information in establishing effluent limits, an application of saltwater and freshwater standards, and allowances to derive site-specific modifications and variances to the standards.

Other amendments facilitated implementation and clarified the standards. These amendments included revisions of sections VR 680-21-01.2 (General Standard and Mixing Zones), VR 680-21-01.4 (Stream Application: Stream Flow), and VR 680-21-07.2 (Outstanding State Resource Waters). Because the new table contained all the standards for surface water, VR 680-21-01.10 (Mercury in Fresh Water), VR 680-21-02.3 (Surface Water Standards for Surface Public Water Supplies), and VR 680-21-03 (Water Quality Criteria) were deleted. The amendments became effective on May 20, 1992 and were submitted to the EPA for review. The EPA approved Section VR 680-21-01.14 in July, 1992 and the agency approved the remaining amendments, including changes to the antidegradation section, in August, 1992.

Shortly after the adoption of these standards, several municipal and industrial wastewater plant owners filed a lawsuit in the State Circuit Court. The suit challenged the standards for mercury, copper, lead, zinc, and ammonia, claiming a failure to account for the impact of the receiving water characteristics on metal toxicity and the natural occurrence of metals in these waters. In June 1993, the court ordered a dismissal of the appellant's case, ruling that the Virginia Department of Environmental Quality acted within the scope of its authority and that its action was both reasonable and based on substantial evidence.

## Point Source Programs

### *PERMITTING PROGRAM*

#### **VPDES Permit Program and Toxics**

Requirements for toxics monitoring are written into Virginia Pollutant Discharge Elimination System (VPDES) permits as special conditions. The Virginia Department of Environmental Quality



Toxics Management Program develops these monitoring requirements which originated in the early 1980s. The program attempts to involve all industrial and municipal VPDES permit holders with the potential to discharge toxics pollutants in a systematic program of biological and chemical testing. This testing should identify those wastewater discharges toxic to aquatic life, the specific substances responsible for this toxicity, and any substances exceeding state criteria or standards.

The need for inclusion of a permittee in the Toxics Management Program is determined at the time of permit issuance, reissuance, or modification using information provided by the permittee as well as additional VPDES data or data from other sources. Generally, the Toxics Management Program special conditions include quarterly chronic and/or acute toxicity testing for one year using both vertebrates and invertebrates. Quarterly chemical testing is required in conjunction with the toxicity testing and includes analyses for all pollutants identified in accordance with Section 307(a) of the Clean Water Act (i.e., Priority Pollutants) as well as for additional organic contaminants detected using appropriate EPA analytical methods. Deviations from standard testing requirements may be made on a case-by-case basis.

Once the Toxics Management Program data have been generated for a particular outfall, they are evaluated according to the following decision criteria specified by the Toxics Management Regulation:

1. The effluent must show no acute toxicity in at least 75 percent of the tests performed.
2. The effluent must show no predicted chronic toxicity in the receiving stream under low flow conditions in at least 75 percent of the tests performed. (Chronic toxicity testing is only applicable to effluents predicted to make up at least 1 percent of the receiving stream during low flow conditions.)
3. Predictions of the effluent's concentration of individual pollutants should be under Virginia's water quality standards or criteria for the protection of human health or aquatic life in the receiving stream.

If an effluent passes criteria 1 and 2, annual toxicity testing is usually required for the life of the permit. If an effluent demonstrates acute and/or chronic toxicity by failing criteria 1 and/or 2 above, the permittee is required to perform a toxicity reduction evaluation which is described below.

In response to the adoption of the water quality standards for toxic chemicals, the Department of Environmental Quality developed an implementation guidance document for permit writers to determine the appropriate effluent limits for affected plants. The guidance was revised due to conflicts with permittees over draft permits containing toxic limits. The updated document became available in June 1993 and has resolved most of the earlier problems. Permits for toxic chemicals are now being drafted and the staff will clear any backlog of pending permits at the state level. Despite the lawsuit filed after the Department of Environmental Quality adopted water quality standards for toxics in March 1992, the staff continued to draft permits in response to the water quality standards. Permits were issued with both acute and chronic limits for whole effluent toxicity.

### **Toxicity Reduction Evaluation**

A toxicity reduction evaluation is a stepwise process to identify specific chemicals or classes of chemicals responsible for the effluent's toxicity and to evaluate and implement treatment alternatives

to reduce the concentrations to acceptable levels. If chemical data indicate that the effluent actually or potentially contributes to violations of water quality criteria and/or standards in the receiving stream, water quality-based permit limits for the parameter of concern should be included in the VPDES permit.

A breakdown of current program statistics for VPDES permits in the Bay drainage area follows:

- Bay area plants in Toxics Management Plan: 279
- Data review of plants indicates toxicity reduction evaluation needed: 18
- Permittees involved in toxicity reduction evaluations: 22
- Plants with completed toxicity reduction evaluations: 7
- Plants that have ceased direct discharge to a receiving stream (off line or connect to publicly owned treatment works): 4
- Plants performing instream impact study = 1

### **Toxics Management Regulation**

Since November 1988, Virginia's Toxics Management Regulation (VR 680-14-03) has driven the Toxics Management Program. Public notification was given that the Virginia Department of Environmental Quality intended to repeal the Toxics Management Regulation to eliminate any confusion or duplication of regulations resulting from the concurrent adoption of a revised VPDES Permit Regulation (VR 680-14-01.1).

The Permit Regulation will include language from the federal NPDES regulations on the evaluation of effluent toxicity and the mechanisms to control toxicity through chemical-specific and whole effluent toxicity limitations. The testing requirements and decision criteria of the Toxics Management Regulation will be used to guide implementation of the toxics control provisions of the VPDES Permit Regulation. Virginia's position on the control of toxic pollutants will not be substantially altered due to these actions.

### **304(l) List**

The 304(l) list refers to a 1987 Clean Water Act section which requires the states to develop a list of plants discharging toxic chemicals (307(a) priority pollutants) in quantities that exceeded state water quality standards or criteria. The 23 plants included in Virginia's 304(l) list that discharge to the Bay drainage area are:

<u>VPDES</u>	<u>PLANT</u>	<u>TYPE</u>	<u>CLASS</u>	<u>BASIN</u>
VA0002178	Merck	IND	Major	Potomac
VA0002208	Avtex Fibers*	IND	Major	Potomac
VA0002402	Genicom	IND	Major	Potomac
VA0002771	Modine Manufacturing**	IND	Major	James
VA0002861	Reynolds - Bellwood	IND	Minor	James
VA0003468	Solite	IND	Minor	James
VA0003492	Aqualon	IND	Minor	James
VA0004031	Holly Farms - Glen Allen	IND	Minor	James
VA0004383	NorShipCo - Berkley	IND	Minor	Elizabeth

## Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

VA0004405	NorShipCo - Brambleton	IND	Minor	Elizabeth
VA0004421	U.S. Navy Sewells Point	FED	Major	James
VA0004791	Georgia Bonded Fibers	IND	Minor	James
VA0005215	Norfolk Naval Shipyard	FED	Major	Elizabeth
VA0006262	Lynchburg Foundry	IND	Minor	James
VA0024970	Lynchburg STP	MUN	Major	James
VA0025151	Waynesboro STP	MUN	Major	Potomac
VA0025216	Fort Eustis STP	FED	Major	James
VA0050962	Narox Inc.	IND	Minor	James
VA0053813	Colonnas Shipyard	IND	Minor	Elizabeth
VA0054607	GE - Charlottesville	IND	Major	James
VA0059145	Culpepper Wood Preservers	IND	Minor	Rappahannock
VA0063177	Richmond STP	MUN	Major	James
VA0066630	Hopewell STP	MUN	Major	James

NOTES:                   \* *Permit revoked; ceased operation 11/89*  
                              \*\* *Connected to POTW*  
                              *STP = sewage treatment plant*  
                              *IND = industrial facility*  
                              *FED = federal facility*  
                              *MUN = municipal facility*

Each listed facility was required to develop an Individual Control Strategy to address its discharge of toxics; all have received approval for their Individual Control Strategies and eight had the provisions of their strategy incorporated into the VPDES permit in the last two years. The 304(l) list plants are being reevaluated in light of the new water quality standards for toxics and effluent limits are being calculated for the permits when necessary. The major difference between these plants and other dischargers with effluent limits for chemicals is that the compliance schedule for 304(l) plants is three years; others will usually have four years.

### ***PRETREATMENT PROGRAM***

The Pretreatment Program is primarily designed to protect publicly owned treatment works (POTWs) and the environment from the adverse impact of toxic wastes discharged into a municipal wastewater system. This protection is achieved by regulating the non-domestic users of those POTWs that discharge toxic or unusually strong conventional waste. The POTWs are not usually designed to treat toxic industrial waste. Such waste may interfere with the plant's biological treatment processes, pass through untreated into receiving waters, or contaminate sludge to the extent that lawful disposal is severely restricted or precluded.

Under the Pretreatment Program, the POTW authorities are responsible for controlling their industrial users. The EPA or delegated states provide oversight and regulation of the program. The Virginia Water Control Board received authorization to administer the Pretreatment Program in April 1989, becoming one of only 25 states with delegated responsibility for all three point source control programs (NPDES Permit; Federal Facilities NPDES Permit; and Pretreatment) authorized under the Clean Water Act.

The following 35 POTWs in Virginia's Bay drainage area now have approved pretreatment programs.

Potomac Basin: Alexandria STP, Arlington STP, Augusta Co. S.A. (6 plants), Harrisonburg/Rockingham STP, Lower Potomac STP, Opequon STP, Upper Occoquan STP, Waynesboro STP.

Rapp. Basin: Culpepper STP, FMC STP, Little Falls Run STP, Massaponax STP.

York Basin: Gordonsville STP, HRSD-York STP.

James Basin: HRSD-Army Base STP, HRSD-Boat Harbor STP, Camelot STP, Falling Creek STP, Henrico STP, Hopewell STP, HRSD-James River STP, HRSD-VIP STP, Lynchburg STP, Moores Creek STP, HRSD-Nansemond STP, Petersburg STP, Proctors Creek STP, Richmond STP, HRSD-Williamsburg STP.

Bay/Coastal: HRSD-Chesapeake/Elizabeth STP.

These plants receive wastewater from 100 industrial categories subject to federal pretreatment standards due to industrial class (e.g., metal finishing, electroplating) and 139 significant non-categorical industries (with process wastewater flow of 25,000 gallons per day or more), which require inspection at the state level. With almost 750 municipalities statewide required to perform industrial waste surveys to determine the types of industries discharging to their systems, the number of significant industrial categories to be inspected by the state should increase over the next few years.

Since authorization, all POTWs with approved programs have been audited yearly and follow-up actions have been taken to correct any deficiencies. All industrial categories identified in Virginia and nearly 270 significant non-categorical industries have been inspected and the owners advised of the findings. All VPDES permits issued to POTWs with approved programs have special conditions for their implementation. Those POTWs with developing programs have an enforceable schedule for submitting a program for approval. The VPDES permits will be amended to include the implementation language when approval is received. Industrial waste surveys are conducted statewide through special conditions in the VPDES permits and are repeated every five years to determine if other authorities will be required to develop pretreatment programs.

There is agreement at all levels of government and industry that national standards are needed for the pretreatment program. Many of the industries listed as categorical in the NPDES program have no promulgated pretreatment standards. The POTWs are then forced to become "miniature regulatory agencies," setting their own industrial user permit limits through extensive sampling and analysis and working with industry to ensure compliance.

## ***STORM WATER MANAGEMENT PROGRAM***

In 1987, Congress amended the Clean Water Act (33 USC 1251 et seq.) requiring the EPA to develop a phased approach in the regulation of stormwater discharges under the NPDES permit program. On November 16, 1990, the U.S. EPA published the final NPDES Permit Application Regulations for Storm Water Discharges (55 FR 47990). These regulations established permit

application requirements for stormwater discharges from municipal storm sewer systems serving a population of 100,000 or more and for those associated with industrial activity.

Eleven municipal storm sewer systems in Virginia's Chesapeake Bay drainage area are required to file stormwater permit applications under the regulations. Of these, three are large municipal systems (serving populations over 250,000) and the rest are medium-sized municipal systems (serving populations between 100,000 and 250,000). Individual permits will be developed and issued for each of the following municipalities under this program:

Cities - Chesapeake, Hampton, Newport News, Norfolk, Portsmouth, and Virginia Beach.

Counties - Arlington, Chesterfield, Fairfax, Henrico, and Prince William.

Two additional localities (Richmond and Alexandria) meet the population criteria in the regulation, but their stormwater discharges are being handled under a different program due to their combined sewers.

The localities affected by the regulations must develop stormwater management programs that include two major elements:

1. A program to reduce the discharge of pollutants from municipal storm sewers to the maximum extent practical; and
2. Adoption and implementation of ordinances to prohibit illicit discharges into stormwater systems (such as illegal hookups or dumping).

The Department of Environmental Quality expects to have a permit issued to each of these localities by mid 1994. The permit will require implementation and monitoring of the program. If stormwater monitoring during the permit term (no longer than five years) shows that the management program is not reducing pollution effectively, then the locality must make improvements.

The regulations define the eleven categories of industrial activities required to apply for stormwater permits. The term "industrial activity" covers: manufacturing facilities; hazardous waste treatment, storage, or disposal facilities; landfills receiving industrial wastes; recycling facilities; steam electric power generating facilities; transportation facilities; domestic wastewater treatment plants greater than one million gallons per day; and construction activities disturbing five or more acres.

An estimated 4,500 industrial facilities and 3,000 to 5,000 construction sites in Virginia may file stormwater permit applications under this program. Individual and general permits will be developed and issued for industrial dischargers. An estimated 2,000 additional facilities have also applied for stormwater permits through EPA's "group application" process. The Department of Environmental Quality will issue stormwater permits to these facilities after the EPA develops model permits for each group and forwards these to the states.

The Department of Environmental Quality administers the federal NPDES permit program under the state VPDES permit program. The permit program is authorized under the State Water Control Law (Sections 62.1-44.15, -44.16, and -44.17 of the Code of Virginia). The Permit Regulation (VR 680-14-01) sets forth the policies and procedures followed in the administration of the permit program.

The federal stormwater regulations require the state to incorporate stormwater permitting into the VPDES permit program.

The federal regulations, guidance documents, and application forms are being used for this program with modification for Virginia's needs. Stormwater permitting requirements are being incorporated into the VPDES permit program and the permit regulations will be modified to incorporate the stormwater permitting requirements, if necessary.

On June 28, 1993, the State Water Control Board adopted four draft VPDES stormwater general permits as emergency regulations. These permits allow the Department of Environmental Quality to cover stormwater discharges from the following categories of dischargers: (a) heavy manufacturing facilities [EPA Category 2 facilities]; (b) light manufacturing facilities [EPA Category 11 facilities]; (c) transportation facilities; landfills, land application sites, open dumps; material recycling facilities; and steam electric power generating facilities; and (d) construction sites. In addition, the department has drafted a general permit for non-metallic mineral mining industries that covers both process water and stormwater discharges.

The general permit emergency regulations will expire one year from the effective date. By that time, the Department of Environmental Quality will have taken the four general permits through the administrative process for permanent adoption. All of the general permits have been submitted to the EPA for comment/approval. The department expects to start issuing the general permits by this fall.

The Department of Environmental Quality's permit section is currently responsible for all stormwater permitting activities. Stormwater permitting activities underway include: Storm Water Permitting Program development--review of Part 1 and Part 2 applications for municipal separate storm sewer systems; development of stormwater general permits; development of stormwater general permit criteria under an EPA 104(b)(3) stormwater grant; and assistance of industrial facilities and municipalities with stormwater permit application problems, questions, and review.

## **Nonpoint Source Programs**

### ***PESTICIDE MANAGEMENT PROGRAM***

The Virginia Pesticide Management Program has undergone significant change since passage of the new Pesticide Control Act in 1989. The creation of a new 11-member (now 12-member) Pesticide Control Board was one of the immediate results of the legislation. As a policy board, this organization has broad powers to enforce the pesticide act.

The Pesticide Control Board has promulgated regulations which control the setting of fees, pesticide businesses, the certification of pesticide applicators, and the establishment of public participation guidelines. The board is working on regulations for the registration of pesticides and the storage and disposal of pesticides.

An estimate of pesticide use on 12 agricultural crops was completed in 1990, followed by a more accurate accounting of through surveys that were carried out in 1991 and 1992 on 20 agricultural crops.

In addition, pesticide use information has been gathered for forestry, gypsy moth control, mosquito control, rights-of-way, and ornamental and lawn care pest control in Virginia. This information is available from the Virginia Department of Agriculture and Consumer Services.

In 1990, Virginia initiated a program to collect and dispose of unwanted pesticides from agricultural producers. This highly successful program has safely and properly removed and destroyed more than 37 tons of pesticides which posed a potential threat to both health and the environment. An additional 100,000 pounds of unwanted pesticides were collected in four localities in 1993.

A pilot program to recycle plastic pesticide containers was implemented in three counties in 1992 and was expanded to six localities in 1993. Thousands of plastic pesticide containers, which would have ended up in landfills or been discarded along state roads, now will be recycled into new products or used for energy production. This program eliminates another potential source of pollution to the environment in general and the Chesapeake Bay in particular.

The Virginia Pesticide Control Board has also funded research for the past three years. Major areas of supported research have focused on: (1) alternatives to traditional chemical pesticides; and (2) the extent of pesticide contamination in Virginia's groundwater. Alternatives to traditional chemical pesticides should reduce the overall use of pesticides and encourage wider application of integrated pest management practices. Data from the groundwater program will add important new information to the understanding of Virginia's hydrogeology and the impact of pesticide use on Virginia's groundwater resources.

A task force completed the drafting of a Generic Pesticides and Ground Water Management Plan for Virginia in May, 1993. Following a comment period, the plan was submitted to the EPA in the fall. This plan forms the basis for future pesticide-specific management plans, if required. The groundwater management plans will establish procedures for protecting human health and the environment.

## **Hazardous Waste Management Programs**

The Waste Division of the Department of Environmental Quality (formerly the Department of Waste Management) is responsible for the regulatory programs which address solid waste, hazardous waste and hazardous materials, and the state Superfund program. These programs encompass management of solid, hazardous, and radioactive waste, emergency planning for hazardous materials (SARA Title III), and hazardous materials transportation activities. Both solid and hazardous waste management present significant planning, regulatory, and enforcement challenges to Virginia with emphasis on identifying waste reduction approaches.

Three types of activities present potential toxic threats to public health and the environment which are within the jurisdiction of the Waste Division. Threats exist from: (1) the use of chemicals in production processes; (2) the subsequent generation, treatment, storage and disposal of hazardous materials (both product and wastes); and (3) the management of solid (non-hazardous) wastes which include household hazardous and industrial wastes.

## ***SOLID WASTE MANAGEMENT PROGRAM***

The Waste Division administers three solid waste programs which support a basinwide toxics reduction strategy: the solid waste management program, waste management planning, and litter control and recycling. "Solid waste" consists of municipal, institutional, commercial, and industrial non-hazardous waste (including regulated medical waste). These wastes include garbage, debris, dewatered sludge, scrap metal, white goods, and other disposed of or abandoned materials, but not wastewater discharges. The Waste Division regulates solid waste management facilities including sanitary, construction/demolition/debris, and industrial landfills; materials recovery facilities; energy recovery and incineration facilities; composting facilities; and solid waste transfer stations.

The storage and disposal of wastes generated is a significant area of concern. Wastes in landfills represent a potential long-term liability although solid waste management programs are now integrating new design standards for land disposal facilities. Older solid waste facilities that do not meet new standards are being phased out of operation by federal mandates.

### **Solid Waste Management Program**

The Solid Waste Management Program is responsible for the permitting and regulation of solid waste management activities. Since 1987, the program has grown to include regulations and programs to address financial assurance for closure and post-closure care of private facilities; medical waste; yard waste composting; current flow and stockpiled tires; and the 1993 Virginia Solid Waste Management Regulations that integrate the federally mandated Subtitle D design and capping specifications.

#### **Milestones:**

1. New regulations, effective March 1993, improve the siting, engineering, design, construction, and operation of waste management activities. Landfill post-closure care and corrective action programs are being upgraded. Siting requirements include wetland considerations.
2. Compliance and enforcement programs were expanded in 1992.
3. Financial assurance for closure and post-closure care of municipal facilities were required as of April 1993.

### **Solid Waste Management Planning**

The Solid Waste Management Planning Program requires the development of policies, programs, and initiatives to address major waste management issues in Virginia. It promotes citizen participation in the development of plans and regulatory programs and informs the public of trends and activities in waste management.

#### **Milestones:**

1. The solid waste management plan draft should be prepared by July 1994.



2. The local and regional solid waste management plans have been reviewed and all but one regional plan have been approved with completion expected by July 1994. All plans must be updated by 1997.
3. Local and regional programs submitted recycling rates in 1993, with all but six programs achieving compliance. Recycling rates must be submitted for staff review by April 1994.

### **Litter Control and Recycling**

The goals of the program are to: 1) reduce the quantities of material entering the waste stream by encouraging recycling; 2) promote proper waste disposal practices to prevent and reduce littering; 3) increase the capabilities of recycling professionals in Virginia; 4) improve the consistency and visibility of litter prevention efforts in Virginia; and 5) ensure the effective allocation and management of resources.

#### **Milestone:**

1. Approve recycling plans and quantity reports from localities to indicate how state-mandated recycling goals are met.

### ***RCRA PROGRAM***

The Waste Division administers five hazardous waste or hazardous materials programs that support a basinwide toxics reduction strategy: a hazardous waste management program; state site certification for hazardous waste management; Virginia Hazardous Waste Capacity Assurance Program; the Virginia Emergency Response Council (SARA Title III); and an environmental response and remediation program. "Hazardous waste" describes either a listed RCRA waste or waste material with ignitable, corrosive, reactive, or toxic properties. In Virginia, the Waste Division regulates treatment/storage facilities, large quantity generators, small quantity generators, and transporters.

Commercial and industrial facilities which generate, store, treat, dispose of, or transport hazardous wastes are subject to RCRA. Virginia has adopted Hazardous Waste Management Regulations which integrate RCRA's requirements for handling hazardous waste from "cradle to grave." Although it is difficult to estimate the amount of hazardous waste produced in Virginia, changes in the regulations in 1990 caused previously unregulated wastes to fall within the domain of RCRA, widening the sphere of regulated wastes. Virginia does not currently have a permitted commercial landfill facility which is chemically secure for the disposal of hazardous waste.

The Hazardous Waste Management Program is responsible for the permitting and regulation of hazardous waste treatment, storage, and disposal facilities along with generators and transporters of hazardous waste. Hazardous wastes are designated or listed wastes or characteristic wastes that may cause substantial present or potential hazard to the public or the environment when improperly managed.

#### **Milestones:**

1. Over 500 large quantity hazardous waste generators exist in Virginia's portion of the Chesapeake Bay watershed.

2. At least four land-based hazardous waste disposal units east of the fall line and three others within the Bay watershed have been closed or are being closed and have or will receive post-closure care permits.
3. As of 1993, no operating permits for land-based hazardous waste disposal units are pending.
4. There is currently a plan for geographic targeting of health and ecological risks within Virginia's portion of the Bay watershed with the focus on performing "risk assessments" of hazardous waste facilities to enable the Department of Environmental Quality to prioritize facilities for inspection.

### **State Site Certification for Hazardous Waste Management**

This regulation addresses the siting of new or expanded hazardous waste management facilities. Site certification is required in addition to permits for the design and operation of these facilities to evaluate off-site environmental impacts.

#### **Milestones:**

1. By December 1995, reassess siting regulations for potential revisions. Regulations are updated every two years.

### **Virginia Hazardous Waste Capacity Assurance Program**

Virginia prepared its first Capacity Assurance Plan in 1989 in response to Section 104(c) (9) of CERCLA. The statute requires that a state must assure that hazardous waste treatment or disposal facilities have adequate capacity to manage the waste reasonably expected to be generated within the state over the next 20 years before EPA will fund remedial actions.

The 1989 Virginia Capacity Assurance Plan received conditional approval from the EPA. Virginia has planned to assure adequate capacity by committing resources to pollution prevention and waste minimization efforts to reduce the generation of waste. Virginia's Capacity Assurance Plan was part of the Northeast States Capacity Assurance Planning Project that was established to develop additional regional treatment and disposal capabilities.

#### **Milestones:**

1. In 1992, the second Capacity Assurance Plan was submitted to and approved by the EPA.
2. The next Capacity Assurance Plan must be submitted by May 1994. If the EPA determines that capacity "shortfalls" exist, based on the aggregate data from all states, Virginia will have to prepare a detailed plan on how it will handle its share of the waste contributing to these shortfalls.

### **SARA Title III Program**

The SARA Title III Program implements a state program in accordance with the federal "Emergency Planning and Community Right to Know Act" of 1986. Since 1987, this program has been responsible for the electronic data base of hazardous chemical information submitted by regulated facilities under SARA Title III. The program functions in an outreach and educational capacity,

providing information to the public and industry and preparing the Annual Toxic Release Inventory Report.

### **Environmental Response and Remediation Program**

The Office of Environmental Response and Remediation was created within the Waste Division in 1992 by combining the activities and personnel of the Emergency Response Program and the State Cleanup Program. The Office of Environmental Response and Remediation responds to releases and improper handling of solid and hazardous wastes and coordinates the cleanup of sites where the wastes remain in the environment. The Office of Environmental Response and Remediation responds to critical releases by providing support for DES and local HazMat Teams 24 hours a day, seven days a week.

#### **Milestones:**

1. Over the past twelve months, the Office of Environmental Response and Remediation received approximately 400 reports of hazardous waste mismanagement. These cases were referred to the responsible office within the Department of Environmental Quality and investigated as appropriate.
2. The Office of Environmental Response and Remediation performed approximately 200 site investigations in response to these reports.
3. The Office of Environmental Response and Remediation is represented on the Tidewater Environmental Task Force, an interagency group that locates improperly handled hazardous materials and waste.

### ***SUPERFUND PROGRAM***

This program provides state participation in the investigation and cleanup of existing or abandoned sites where serious threats to human health or the environment exist due to past disposal practices or continued releases from non-permitted facilities. Three programs exist within the state Superfund Program.

Through the Site Assessment Program, sites are investigated to determine whether action is warranted. In partnership with EPA Region III, the Remedial Program investigates and performs the cleanup of Virginia's National Priority List (NPL) sites. As of 1992, 23 NPL sites are in the state with at least 15 in Virginia's portion of the Chesapeake Bay watershed. Based on a 1990 agreement, the commonwealth has provided technical assistance to 30 Department of Defense installations to assure compliance with state standards and regulations.

#### **Milestones:**

1. Since 1988, staff have completed more than 100 preliminary assessments.
2. Of the 15 NPL sites in the Virginia portion of the Chesapeake Bay watershed, five are east of the fall line. To date, one site has been cleaned up, six are in the cleanup stage, one is in the design

stage, one is in the design negotiation stage, four are in the study stage, and two have yet to be addressed. Three sites are Department of Defense facilities.

## **Air Quality Control Program**

The Air Toxics Program in the Department of Environmental Quality (formerly the Department of Air Pollution Control) is charged with implementing and improving the applicable provisions of the state's air quality regulatory requirements. In 1989, following a four-year pilot program, the department began a statewide evaluation of chemical emissions from existing facilities while reviewing new and modified permit applications for chemical emissions under the state program. Between 1988 and 1990, approximately 300 facilities were inventoried statewide (including facilities near the Chesapeake Bay). This inventory identified chemicals that led to the development of some permit limits and testing requirements. With the passage of the 1990 Clean Air Act Amendments, the inventory process was curtailed because the federal operating permit requirements of the act would accomplish the same goal as the earlier state inventory.

The state toxics program is an established part of the department's facility review procedure with its toxics regulations addressing 238 toxic chemicals and compounds. The development of a toxics data base has been delayed but is being revived under requirements of the 1990 Clean Air Act Amendments.

Since the signing of the 1988 Basinwide Toxics Reduction Strategy, the department has:

- Provided emission inventory data to Chesapeake Bay Program contractors.
- Conducted one year (1990) of toxics canister sampling of 41 volatile organic compounds in the Tidewater (Hampton) area.
- Conducted two years (1989 to 1990) of non-methane organic compound canister sampling in Norfolk and one year (1990) of non-methane organic compound canister sampling in Chesapeake. Due to a reduction in department resources, the only current canister sampling is in Hopewell.

## **Atmospheric Deposition**

Other monitoring activities near the Bay include:

- Acid precipitation monitoring at Hampton and West Point for pH, ammonium, fluoride, chloride, bromide, nitrate, sulfate, and phosphate; and
- Chesapeake Bay Atmospheric Deposition Study (Mathews County, Haven Beach).

Researchers from the Virginia Institute of Marine Sciences and Old Dominion University are measuring metals and organic contaminants in atmospheric deposition at Haven Beach, Virginia. The objectives of this study are to measure the concentration of metals and organic contaminants in precipitation and atmospheric aerosols precisely, determine the temporal and spatial variability in precipitation and aerosol concentration and the corresponding fluxes, evaluate the relative magnitude of atmospheric depositional processes, and to estimate the annual atmospheric loading to the Bay's surface waters.

**Future Actions:**

- The 1990 Clean Air Act Amendments requires a toxics emission inventory of all applicable facilities in Virginia. The initial survey of these sources began in the late summer of 1993. This information will be updated annually, providing a more extensive and accurate inventory of emissions. This information should be available to interested parties by mid-1994.
  - The 1990 Clean Air Act Amendments Great Waters Provisions (Section 112(m)) include Chesapeake Bay. Emissions inventory data will be used to determine atmospheric loadings of toxic pollutants into the Bay. Updates of the toxics emission inventory should support periodic assessments and provide data for more refined atmospheric dispersion models of the Bay.
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## **APPENDIX B**

### **Chesapeake Bay Basin States 304(I) Facilities**





# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

<b>FACILITY NAME</b>	<b>NPDES NO.</b>	<b>TRIBUTARY DIRECTLY DISCHARGED TO:</b>	<b>MAJOR TRIBUTARY BASIN</b>
<b><u>NEW YORK</u></b>			
Corning Inc.	NY003972	Cohocoton River	Susquehanna River
<b><u>PENNSYLVANIA</u></b>			
Armstrong World	PA0008761	Susquehanna River	Susquehanna River
Glatfelter Paper	PA0008869	Codorus Creek	Susquehanna River
United Piece Dye Works	PA0009172	Susquehanna River	Susquehanna River
Cerro Metals	PA0009202	Logan Branch	Susquehanna River
Lowengart and Co. - Mercersburg	PA0009521	Johnston Run	Susquehanna River
Penlec - Shawville	PA0010031	West Branch	Susquehanna River
Letterkenny Army Depot	PA0010502	Rowe Run	Susquehanna River
York City Sewer Authority	PA0020621	Codorus Creek	Susquehanna River
Nawkein Boro Authority	PA0020893	Chickies Creek	Susquehanna River
Huntington Water and SA	PA002691	Juniata River	Susquehanna River
Scranton Sewer Authority	PA002692	Lackawanna River	Susquehanna River
Throop Sewer Authority	PA0027090	Lackawanna River	Susquehanna River
Penn Township	PA0037150	Oil Creek	Susquehanna River
New Freedom Boro	PA0043257	S. Branch Codorus Creek	Susquehanna River
Pittman-Moore (Inc. Chemical)	PA0070505	Jordan Creek	Susquehanna River
Westfield Tanning Co.	PA0008800	Susquehanna River	Susquehanna River
Wyeth - A Yerst Lab	PA0013862	Susquehanna River	Susquehanna River
York City Wastewater	PA0026263	Susquehanna River	Susquehanna River
Mountain Top Area	PA0045985	Susquehanna River	Susquehanna River
<b><u>MARYLAND</u></b>			
Delmarva Power & Light	MD0000094	Nanticoke River	Nanticoke River
WR Grace Company	MD0000311	Curtis Bay	Patapsco River
Amoco Oil Baltimore Asphalt TE	MD0000388	Curtis Bay	Patapsco River
Eastern Stainless	MD0000981	Bacon Creek	Patapsco River
General Motors	MD0001163	Colgate Creek	Patapsco River
Bethlehem Steel - Baltimore	MD0001201	Bear Creek	Patapsco River
SCM Chemicals	MD0001270	Colgate Creek	Patapsco River
Sherwin-Williams	MD0001296	Gwynns Falls	Patapsco River
Carr - Lowery Glass Company	MD0001414	Middle Branch	Patapsco River
Chemetals Corporation	MD0001775	Arundel Cove	Patapsco River
Nevamar Corporation (003)	MD0002003	Picture Spring Branch	Severn River
SCM Hawkins Point Plant	MD0002161	Patapsco River	Patapsco River
Chesapeake Park	MD0002852	Dark Head/Cowpen Creeks	Patapsco River
David Taylor NS&DC	MD0003051	Severn River	Severn River
Universal Foods	MD0003298	Colgate Creek	Patapsco River
Back River WWTP	MD0021555	Back River	Back River
Salisbury WWTP	MD0021571	Wicomico River	Wicomico River
Fallston WWTP	MD0052141	Wildcat Branch	Patapsco River
BG and E - Brandon Shores	MD0054321	Patapsco River	Patapsco River

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

FACILITY NAME	NPDES NO.	TRIBUTARY DIRECTLY DISCHARGED TO:	MAJOR TRIBUTARY BASIN
G & S Coal	MD0058238	Jennings,RP Three Fork Run	Potomac River
Winner Brothers Coal Company	MD0058416	Vale Run, Georges Creek	Potomac River
Reichs Ford Landfill	MD0061093	Bush Creek	Potomac River
MES Hawkins Point Landfill	MD0061417	Thons Cove	Potomac River
Garret Round Glade	MD0061646	Round Glade Run	Potomac River

## DISTRICT OF COLUMBIA

Blue Plains WWTP	DC0021199	Potomac River	Potomac River
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## DELAWARE

No 304(l) facilities within the Chesapeake Bay basin.

## Virginia

Merck & Company	VA0022178	South Fork Shenandoah River	James River
Avtex Fibers (003, 004)	VA0002208	South Fork Shenandoah River	James River
Genecom Corporation	VA0002402	South River	Potomac River
Modine Manufacturing	VA0002771	Indian Gap Run	James River
Reynolds Metals - Bellwood	VA0002861	Proctors Creek	James River
Solite	VA0003468	James River	James River
Aqualon (001, 002)	VA0003492	Cattail Creek	James River
Holly Foods Farms	VA0004031	Chickahominy River	James River
Norshipco - Berkely (007,8,9)	VA0004383	South Branch Elizabeth River	James River
Norshipco - Brambleton	VA0004405	Elizabeth River	James River
US Navy - Sewells Pt. (74,75)	VA0004421	James River	James River
Georgia Bonded Fibers	VA0004791	Maury River	James River
Norfolk Naval Shipyard	VA0005215	South Branch Elizabeth River	James River
Lynchburg Foundry	VA0006262	James River	James River
Lynchburg	VA0024970	James River	James River
Waynesboro	VA0025151	South River	Potomac River
Fort Eustis	VA00252216	James River	James River
Narox (001,002)	VA0050962	Shand Creek	James River
Collonas Shipyard (004)	VA0053813	East Branch Elizabeth River	James River
GE - Charlottesville	VA0054507	Herring Branch	James River
Culpepper Wood Preserves	VA0059145	Jonas Run	Rappahannock River
Richmond STP	VA0063177	James River	James River
Hopewell POTW	VA0066630	Gravelly Run	James River

## WEST VIRGINIA

No 304(l) facilities within the Chesapeake Bay basin.

## **APPENDIX C**

### **Chesapeake Bay Basinwide Toxics Reduction Strategy– Commitments Matrix**



## Chesapeake Bay Basinwide Toxics Reduction Strategy- Commitments Matrix

TOXICS REDUCTION STRATEGY COMMITMENT		IMPLEMENTATION DATE	STATUS
<b>Toxics Assessment (TA)</b>			
TA-1	Support a program of directed research.	Ongoing	<b>Ongoing.</b> Joint NOAA/TSC funds supported continuation of the Chesapeake Bay Toxics Research Program in FY 1993. [CBEEC/Rickards (804) 924-5965]
TA-2	Complete a basinwide survey of existing analytical capabilities.	7/91	<b>Completed 1/91.</b> Copies of the survey available upon request from EPA CBPO.
TA-2.1	Develop the analytical capabilities survey workplan.	12/89	<b>Completed 12/89.</b> Copies of the workplan available upon request from EPA CBPO.
TA-3	Develop a comprehensive listing of data needs for management and assessment of toxics.	Ongoing	<b>Completed 1/93.</b> Copies of the Toxics Reduction Strategy Reevaluation Report available upon request from EPA CBPO.
TA-3.1	Develop and update a complete set of narrative descriptions of all ongoing toxics monitoring.	7/89	<b>Completed 8/89.</b> Copies of Chesapeake Bay Basin Monitoring Program Atlas available upon request from EPA CBPO.
TA-3.2	Develop a listing of data needs, evaluate utility of existing toxics monitoring, design and implementation of new monitoring programs.	12/89	<b>Completed 1/93.</b> Copies of the Toxics Reduction Strategy Reevaluation Report available upon request from EPA CBPO.
TA-4	Develop, support, and maintain a basinwide toxics database.	Ongoing	See specific commitments TA-4.1, TA-4.2 and TA-4.3 below.
TA-4.1	Develop a workplan for the basinwide toxics database.	7/89	<b>Completed 7/91.</b>
TA-4.2	Update and revise the data management plans to include guidelines for the format and submission of toxics data.	12/89	<b>Completed 9/91.</b> Copies of the Chesapeake Bay Program Data Management Plan available upon request from EPA CBPO.
TA-4.3	Complete development of the basinwide toxics database.	7/90	<b>Ongoing.</b> Toxics data sets being acquired according to priorities established by the Toxics Subcommittee's Criteria and Standards workgroup. Data to support Toxics of Concern Ranking System also being ac-

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT	IMPLEMENTATION DATE	STATUS
		quired. [TSC/LRSC Criteria and Standards Workgroup/Garreis (410) 631-3618]
TA-5 Develop and maintain a basinwide toxics loading inventory.	Ongoing	See specific commitments below.
TA-5.1 Develop a workplan for the toxics loading inventory.	12/89	<b>Completed 12/89.</b> Copies of the Basinwide Toxics Loading Inventory Workplan available upon request from EPA CBPO.
TA-5.2 Complete development of the toxics loading inventory.	12/90	<b>Completed 1/94.</b> Copies of the Basinwide Toxics Loading and Release Inventory report available upon request from EPA CBPO.
TA-5.3 Review, expand and revise the toxics loading inventory every two years.	12/92	<b>Ongoing.</b> Inventory's point source loadings updated with facility specific data 4/94; inventory to be fully updated by 4/97. [TSC Toxics Inventory Workgroup/Velinsky (301) 984-1908]
TA-6 Develop and update a toxics of concern list, maintain supporting matrix information and utilize the list to establish toxics.	Ongoing	See specific commitments TA-6.1 through TA-6.4.
TA-6.1 Hold a public meeting to invite public input on the toxics of concern workplan.	9/89	<b>Completed 12/89.</b>
TA-6.2 Complete the toxics of concern workplan.	12/89	<b>Completed 1/90.</b> Copies of the Toxics of Concern workplan available upon request from EPA CBPO.
TA-6.3 Develop an initial Toxics of Concern list.	3/90	<b>Completed 1/91.</b> Copies of the Chesapeake Bay Toxics of Concern report available upon request from EPA CBPO.
TA-6.4 Review and revise the toxics of concern list every two years thereafter.	3/92	<b>Completed 3/92.</b> Copies of the revisions to the Chesapeake Bay Toxics of Concern List available upon request from EPA CBPO. The next update to the list is scheduled to be completed by 9/94. [TSC/LRSC Criteria and Standards Workgroup/Garreis (410) 631-3618]

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT	IMPLEMENTATION DATE	STATUS
TA-7 Support and promote interdisciplinary analysis and reporting of toxics monitoring and research findings.	Ongoing	<b>Ongoing</b> through the joint Toxics Subcommittee/NOAA toxics research program and STAC sponsored workshops and the literature synthesis papers process. [NOAA CBEEC/Rickards (804)924-5965; STAC/Randall (703) 231-6018].
TA-8 Convene a scientific workshop to develop protocols for the use of biological indicators to monitor the effects of contaminants on living resources in their habitats	7/89	<b>Completed 7/89.</b> Copies of the workshop report is available upon request from EPA CBPO.
TA-9 Develop and implement a plan for Baywide assessment and monitoring of effects of toxics on living resources within their natural habitats.	12/89	<b>Completed 1/90.</b> Implementation ongoing through the Chesapeake Bay Ambient Toxicity Assessment Program. Copies of the reports from the first three years of the program available upon request from EPA CBPO.

## Water Quality Standards and Habitat Requirements (WQ)

WQ-1 Adopt necessary water quality standards during the upcoming triennial reviews for 307(a) priority pollutants in accordance with the Clean Water Act.	Ongoing*	<b>Completed.</b>
WQ-2 Increase annual rate of national criteria publication.	Ongoing	See commitment WQ-4.1.
WQ-3 Agree to a consistent definition for the application of national freshwater and saltwater criteria and advisories within the Chesapeake Bay watershed.	7/89	<b>Completed 2/90.</b> Copies of the consistent definition agreement are available upon request from EPA CBPO.
WQ-4 Place priority on developing national water quality criteria and advisories for the Bay toxics of concern.	Ongoing	See commitment WQ-4.1.
WQ-4.1 Submit to the EPA Office of Water, Criteria and Standards Division, a list of toxic compounds for priority	3/90	<b>Completed 2/91.</b>

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT	IMPLEMENTATION DATE	STATUS
consideration in development of water quality criteria and advisories every year.		
WQ-5 Collectively review the EPA criteria and advisories issued for the Bay toxics of concern and consider their adoption as standards.	Ongoing	<b>Ongoing.</b> [TSC/LRSC Criteria and Standards Workgroup/Garreis (420)631-3618]
WQ-6 Issue guidance on use of water quality standards to address nonpoint sources of toxics.	12/89	<b>No progress</b> has been made on this commitment.
WQ-7 Explore means to using more generic approaches to regulating classes of toxic substances and pesticides.	Ongoing	<b>No progress</b> has been made on this commitment.
WQ-8 Use the information in the <i>Habitat Requirements for Chesapeake Bay Living Resources</i> report as guidance in toxics management programs.	Ongoing	<b>Ongoing.</b> Updated version of 1988 report comparing state water quality standards and living resource habitat requirements scheduled for completion 9/94. [TSC/LRSC Criteria and Standards Workgroup/Garreis (410) 631-3618].

## Pt Sources (PS)

PS-1	Develop and submit to EPA lists of waters impacted by toxics in accordance to section 304(l) of the Clean Water Act.	2/89*	<b>Completed 2/89.</b>
PS-2	Develop and implement toxics management programs including the following components: schedule for requiring toxics monitoring in priority discharger permits, consistent testing, and requirements for initiating toxic reduction evaluations.	12/89*	<b>Ongoing.</b> Priority dischargers have been identified in MD, VA and PA. Consistent criteria for defining acute/chronic toxicity have been developed and approved by the TSC as of 2/22/90. [TSC Toxics Inventory Workgroup/Velinsky (301) 984-1908]
PS-3	Provide guidance for including the assessment control of concentrative contaminants in surface water management programs.	1/90*	<b>Ongoing.</b> Draft guidance published 3/91. No date for the publication of the final guidance has been at this time. [EPA OW OST, Feldpausch (202) 260-8149]



# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT	IMPLEMENTATION DATE	STATUS
PS-4 Develop a workplan for conducting a program to “fingerprint” effluent, sediment and tissue samples at selected point sources discharges.	7/90	Draft workplan developed 8/91; <b>no further progress</b> has been made on this commitment. [TSC Toxics Inventory Workgroup/Velinsky (301) 984-1908]
PS-5 Develop workplan for conducting toxicity studies selected point source discharges.	7/90	Draft workplan developed 8/91; <b>no further progress</b> has been made on this commitment. [TSC Toxics Inventory Workgroup/Velinsky (301) 984-1908]
PS-6 Incorporate chemical and biological toxics monitoring requirements in the permits of all priority dischargers.	7/91*	See commitment PS-2 status.
PS-7 Ensure all dischargers identified in the 1989 304(l) lists are in compliance with their individual control strategies.	6/92*	<b>Ongoing</b> in all states. [EPA Region 3/Henry (215)597-8243; States]
PS-8 Ensure all major dischargers not included on the 1989 304(l) lists are in compliance with their toxicity reduction evaluations.	7/96*	<b>Ongoing</b> in all states. [EPA Region 3/Henry (215)597-8243; States]
PS-9 Conduct timely and appropriate enforcement action and spot checks of self-monitored permittees.	Ongoing*	<b>Ongoing.</b> EPA Region 3, Permit Enforcement Branch, has taken the lead in developing the Chesapeake Bay compliance initiatives designed to cut the number of significant violators in half in fulfillment of Admin. Reilly’s increased enforcement commitment. EPA staff have been meeting with the states to develop and implement the strategy to achieve this objective. [EPA Region 3/Piotrowski (215) 597-9078; States]
PS-10 Continue development and implementation of the Permit Compliance System for NPDES permits to include archival of data.	Ongoing	<b>Ongoing.</b> EPA Region 3, Permits Enforcement Branch, has committed to working with the states to increase PCS use. [EPA Region 3/Piotrowski (215)597-9078; States]

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT		IMPLEMENTATION DATE	STATUS
<b>Pretreatment (PT)</b>			
PT-1	Inspect and audit those POTWs with basis.	Ongoing*	<b>Ongoing</b> in all states. [EPA Region 3/Lovell (215)597-6279; States]
PT-2	Inspect selected categorical dischargers annually and the remaining dischargers at least once during the term of the POTW permit.	Ongoing*	<b>Ongoing</b> in all states. [EPA Region 3/Lovell (215)597-6279; States]
PT-3	Take appropriate enforcement and follow-up action against non-complying POTWs.	Ongoing*	<b>Ongoing</b> in all states. [EPA Region 3/Lovell (215)597-6279; States]
PT-4	Investigate new candidate POTWs for pretreatment program development as necessary.	Ongoing*	<b>Ongoing</b> in all states. [EPA Region 3/Lovell (215)597-6279; States]
PT-5	Conduct sampling at priority POTWs at least annually and at significant dischargers when necessary.	Ongoing*	<b>Ongoing</b> in all states. [EPA Region 3/Lovell (215)597-6279; States]
<b>Urban (UR)</b>			
UR-1	Develop consistent methodologies for estimating loads/load delivery calculations for developed urban areas.	12/89	<b>Completed 4/91.</b> Copies of the report available upon request from EPA CBPO.
UR-2	Use the developed methodology to quantify and characterize toxic loads from urban areas.	12/90	<b>Completed 4/91.</b> Results incorporated into the Basinwide Toxics Loading Inventory.
UR-3	Develop programs to regulate urban stormwater discharges following promulgation of EPA regulations.	12/89	<b>Ongoing.</b> Further action dependent on final stormwater regulation promulgation. [EPA Region 3; States]
<b>Pesticides (PE)</b>			
PE-1	Summarize and analyze baseline demonstration watershed data relative to pesticides.	Ongoing*	<b>Completed 6/90.</b>

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT	IMPLEMENTATION DATE	STATUS
PE-2 Complete a pesticide use survey of the Chesapeake Bay basin and utilize the findings to target Integrated Pest Management programs.	12/89	<b>Completed 5/91.</b> Results incorporated into the Basinwide Toxics Loading and Release Inventory.
PE-3 Review existing Integrated Pest Management and sustainable agriculture programs and develop alternatives for their increased utilization.	12/89	<b>Ongoing.</b> CBP funds being awarded annually enhancement of state IPM implementation. [TSC Pesticides Workgroup/Bingaman (717) 772-5214]
PE-4 Implement necessary new/expanded pesticide monitoring.	12/90	<b>Ongoing.</b> Watershed based pesticide monitoring programs initiated in FY91. [TSC Pesticides Workgroup Bingaman (717)772-5214]
PE-5 Identify additional pesticide management programs.	12/91	<b>Ongoing.</b> Being addressed through PE-3. [TSC Pesticides Workgroup/Bingaman (717) 772-5214]
PE-6 Review methods for improving coordination between the Toxics Substances Control Act process and the information needed on aquatic toxicity for water quality programs. Explore development of a basinwide and national toxic registry of chemicals that are preferred for use due to limited environmental impact.	Ongoing	<b>No progress</b> has been made on this commitment.

## Air Deposition (AD)

AD-1 Make available pertinent atmospheric deposition monitoring data to the toxics data base and utilize the information redirect ongoing and future monitoring network and computer model to interpret the data.	12/89	<b>Completed 7/91.</b>
AD-2 Continue national research efforts on atmospheric deposition in the Chesapeake Bay Basin and develop a national monitoring network and computer model to interpret the data.	Ongoing	<b>Ongoing.</b> Work underway through implementation of Great Waters section of Clean Air Act Amendments. [Air Quality Coordination Group/Hicks (301) 713-0295].

## Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT		IMPLEMENTATION DATE	STATUS
AD-3	Continue to build toxic emissions inventories.	Ongoing*	Ongoing in all the states. [States]
AD-4	Take advantage of innovative technologies.	Ongoing	Ongoing in all the states. [States]
AD-5	Support long-term research into the mechanism of pollutant transfer between air and water.	Ongoing	Ongoing. Baywide atmospheric deposition station network initiated summer 1990. Research focused on this is funded through the Chesapeake Bay Toxics Research Program. Additional research supported through implementation of Great Waters section of the Clean Air Act Amendments. [Air Quality Coordination Group/Hicks (301) 713-0295].
AD-6	Designate and maintain permanent monitoring stations in the Bay to measure long term trends in the atmospheric deposition of toxics.	Ongoing*	Ongoing. Baywide atmospheric deposition station network initiated in summer 1990. [Air Quality Coordination Group/Hicks (301) 713-0295].

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### Solid and Hazardous Wastes (HW)

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HW-1	Promote hazardous waste minimization by conducting information exchange and public education activities and setting reduction targets where appropriate.	Ongoing*	Ongoing in the states. [EPA Region 3; States]
HW-2	Comply with the Superfund Amendments and Reauthorization Act 104(k) capacity assurance certification requirements.	Ongoing*	Ongoing in the states. [EPA Region 3; States]
HW-3	Develop and initiate an inspection program for RCRA facilities within the Bay watershed.	10/89*	Ongoing in the states. [EPA Region 3; States]
HW-4	Comply with the Superfund Amendments and Reauthorization Act 104(k) capacity assurance certification requirements.	Ongoing*	Ongoing in the states. [EPA Region 3; States]

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT	IMPLEMENTATION DATE	STATUS
HW-5 Coordinate SARA title III reporting requirements with the Federal Facilities in the Bay basin.	Ongoing*	<b>Ongoing.</b> Work underway at EPA Headquarters.
HW-6 Prioritize site cleanups for solid and hazardous waste sites where there is likely impacts on living resources.	Ongoing*	<b>Ongoing</b> in the states and at EPA Region 3.

## Contaminated Sediments (CS)

CS-1 Design and implement a long-term sediment monitoring program.	12/89	<b>Completed 12/92.</b> Copies of the Chesapeake Contaminated Sediments Critical Issue Forum proceedings available upon request through EPA CBPO.
CS-2 Promote technology transfer of information on sediment toxicity testing to scientific and regulatory communities.	Ongoing	<b>Ongoing.</b> Two year estuarine sediment bioassay method development program completed. Copies of resultant report available upon request through EPA CBPO. EPA Headquarters funding a national effort to develop standardized protocols. [EPA CBPO/Batiuk (410) 267-5700]
CS-3 Implement toxicity testing of sediments within the Chesapeake Bay watershed.	Ongoing	<b>Ongoing</b> through Chesapeake Bay Ambient Toxicity Assessment Program. [TSC/Regions of Concern Workgroup/Kennedy (804) 762-4312.
CS-4 Develop a Chesapeake Bay specific sediment quality	12/91	See commitment CS-3.
CS-5 Incorporate appropriate sediment protocols into the toxics management programs.	Ongoing	Action dependent on completion of CS-2, CS-3 and CS-4. [States]
CS-6 Complete a study of the feasibility of developing a Superfund type program from contaminated sediments.	12/90	<b>Ongoing.</b> EPA Office of Superfund is currently working with EPA Office of Water/ Office of Science and Technology to field test sediment criteria (under development) in defining Superfund sites and cleanup levels. [EPA OW OST/Zarba (202)260-1326]

# Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT		IMPLEMENTATION DATE	STATUS
<b>Strategy Implementation (SI)</b>			
SI-1	Establish an ad hoc panel to develop a strategy plan.	1/89	<b>Completed 5/89.</b> Copies of the report are available upon request through EPA CBPO.
SI-2	Develop a strategy implementation action plan.	7/89	<b>Completed 1/90.</b>
SI-3	Develop and begin implementing a plan to increase program coordination to address cross-media impacts of toxics.	12/89	<b>Completed 1/90.</b>
SI-4	Coordinate toxic reduction initiatives with the basin's federal facilities and the Program's federal agencies.	Ongoing	<b>Ongoing</b> through the Federal Agencies Committee. [FAC/Matuszeski (410)267-0061]
SI-5	Complete the design of a system for measuring progress under the basin-wide strategy	12/89	<b>Completed 12/92.</b> Copies available upon request through EPA CBPO.
SI-6	Produce a Basinwide Toxics Reduction Strategy Progress Report every other year.	12/90 12/92	<b>Completed 9/94.</b> Progress described in the Basinwide Toxics Reduction Strategy Reevaluation report.
SI-7	Reevaluate the Basinwide Toxics Reduction Strategy.	12/92	<b>Completed 9/94.</b> Results described in the Basinwide Toxics Reduction Strategy Reevaluation Report. Toxics Research Strategy Recommendations
<b>Toxics Research Strategy Recommendations</b>			
I.1b	Research to develop an environmental risk assessment protocol for use in the Basinwide Toxics Strategy.	NOAA Chesapeake Bay Environmental Effects Committee 1993 RFP targets research focused on toxic impacts on the Bay's trophic dynamics necessary to support ecological risk assessment protocol development for the Bay. Further work on framing out an ecological risk assessment protocol is needed. [CBEEC/Rickards (804) 924-5965]	
I.2b	Research focused on improving effectiveness of environmental risk assessment protocols.	NOAA Environmental Effects Committee 1993 RFP targets research focused on toxic impacts on the Bay's trophic dynamics necessary to support ecological risk assessment protocol development for the Bay. [CBEEC/ Rickards (804) 924-5965]	

## Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT		IMPLEMENTATION DATE	STATUS
II.1b	Research to determine proper nonpoint source sampling techniques.	Nonpoint Source Subcommittee investigating research status and needs [NPSC/Funk (717) 787-5259]	
II.2b	Research to estimate relative magnitudes inputs of toxics to the Chesapeake Bay.	Atmospheric deposition of toxics to be monitored at a coordinated 3 station network with emphasis on sampling methods refinement. Survey of Baywide fall toxics loadings initiated in 1990 to quantify loads and develop toxic load estimation techniques. [Air Quality Coordination Group/ Hicks (301) 713-0684]	
II.3b	Research to determine appropriate mechanism to couple analytical data systems and exchange of data between laboratories.	Specific research needs identified through the basinwide analytical capabilities survey. See commitment TA-2.1.	
II.4b	Research to develop techniques to minimize application of chemicals to agricultural and urban lands.	[NPSC/Funk (717) 787-5259]	
III.1b	Research to determine processes controlling consolidation and area.	Chesapeake Bay Toxics Research Program is supporting work in this [NOAA CBEEC/Rickards (804) 924-5965] sediments.	
III.2b	Research to determine extent and rates of sediment mixing by in this area.	Chesapeake Bay Toxics Research Program is supporting work in this [NOAA CBEEC/Rickards (804) 924-5965] benthic organisms.	
III.3b	Research to determine importance of non-benthic organisms in fate and transport of toxics.	Chesapeake Bay Toxics Research Program is supporting work in this in this area. [NOAA CBEEC/Rickards (804) 924-5965]	
III.4b	Research to determine constants and coefficients of toxics among various Bay system components.	Chesapeake Bay Toxics Research Program is supporting work in this in this area. [NOAA CBEEC/Rickards (804) 924-5965]	
III.5b	Research to determine appropriate chemical markers for monitoring transport and distribution of toxics.	Research underway at a number of Bay research institutions. [STAC/Randall (703) 231-6018]	
III.6b	Research to determine aerobic and anaerobic biodegradation kinetics. Work in this area.	Chesapeake Bay Toxics research Program is supporting [NOAA CBEEC/Rickards (804) 924-5965]	
IV.1b	Research to prepare a critical summary of knowledge concerning implications of toxics in the Bay.	Work in progress through STAC sponsored literature synthesis process. [STAC/Randall (703) 231-6018]	

## Chesapeake Bay Basinwide Toxics Reduction Strategy Reevaluation Report

TOXICS REDUCTION STRATEGY COMMITMENT		IMPLEMENTATION DATE	STATUS
IV.2b	Research to determine the effectiveness of various toxicity testing alternatives for population, community and ecosystem effects.		Through the Ambient Toxicity Assessment Pilot Study, various water column and sediment bioassay techniques and biomarker tests were field tested for sensitivity to detect ambient toxicity. The EPA Environmental Monitoring and Assessment Program's Virginian Province Pilot Program also conducting field tests. [TSC Regions of Concern Workgroup/ Kennedy (804) 762-4312]
IV.3b	Research to construct a tiered toxicity testing approach within the Basinwide Strategy framework.		Through the Ambient Toxicity Assessment Pilot Study, various water column and sediment bioassay techniques and biomarker tests are being field tested for sensitivity to detect ambient toxicity. [TSC Regions of Concern Workgroup/Kennedy (804) 762-4312]
IV.4b	Research to evaluate effectiveness of various biomarker assays in determining chemical stress.		The Society of Environmental Toxicology and Chemistry has compiled a descriptive compendium of existing biomarker tests. Chesapeake Toxics Research Program has supported work in this area. [NOAA CBEEC/Rickards (804) 924-5965]
IV.5b	Research to determine realistic toxicity exposure regimes and appropriate species.		Through the Ambient Toxicity Assessment Pilot Study, various water column and sediment bioassay techniques and biomarker tests will be field tested for sensitivity to detect ambient toxicity. [TSC Regions of Concern Workgroup/Kennedy (804) 762-4312]

**NOTES** The lead contact for each commitment is the first name listed at the end of the status description. A phone number is also provided.

The dates with an asterisk (\*) indicate commitments that are regulatory mandates.

The bold dates in brackets under the Implementation Date column are the revised dates for completion of the respective commitments.

**KEY** CBEEC - Chesapeake Bay Environmental Effects Committee 778  
 CBPO - Chesapeake Bay Program Office  
 EPA - Environmental Protection Agency  
 CSC - Computer Sciences Corporation  
 EPA ERL-Newport - EPA Environmental Research Laboratory, Newport, Oregon  
 EPA OW OST - EPA Office of Water, Office of Science and Technology  
 FAC - Federal Agencies Committee  
 LRSC - Living Resources Subcommittee  
 STAC - Scientific and Technical Advisory Committee  
 TSC - Toxics Subcommittee









