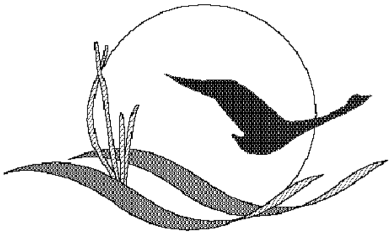
Chesapeake Bay Basin Toxics Loading and Release Inventory

May 1999



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Executive Summary

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.

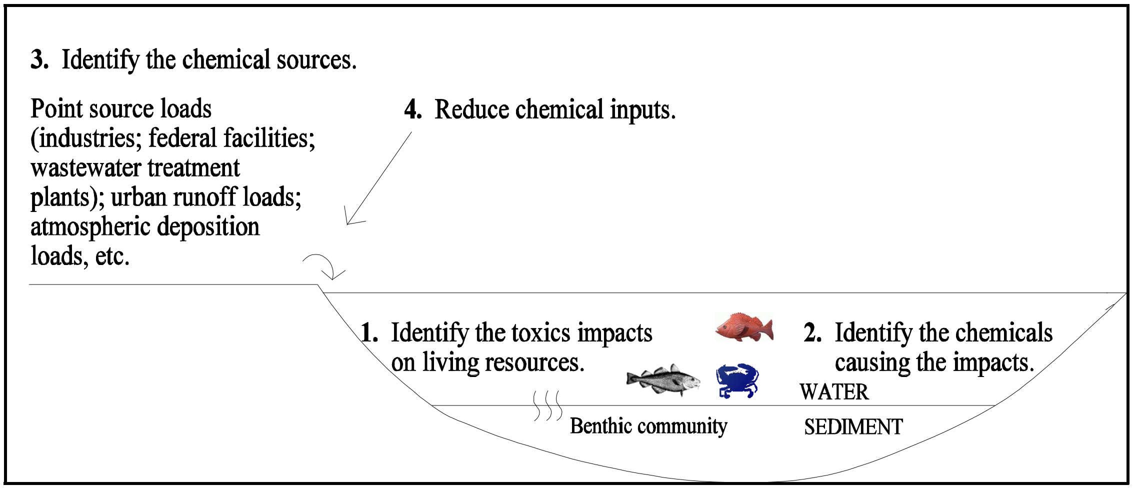


Figure 1. Chesapeake Bay Program process for managing chemical contaminant-related problems in the Bay and its rivers. This figure illustrates that the loading data reported in this inventory are only one piece of the overall toxics management picture. The inventory must be used in conjunction with data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

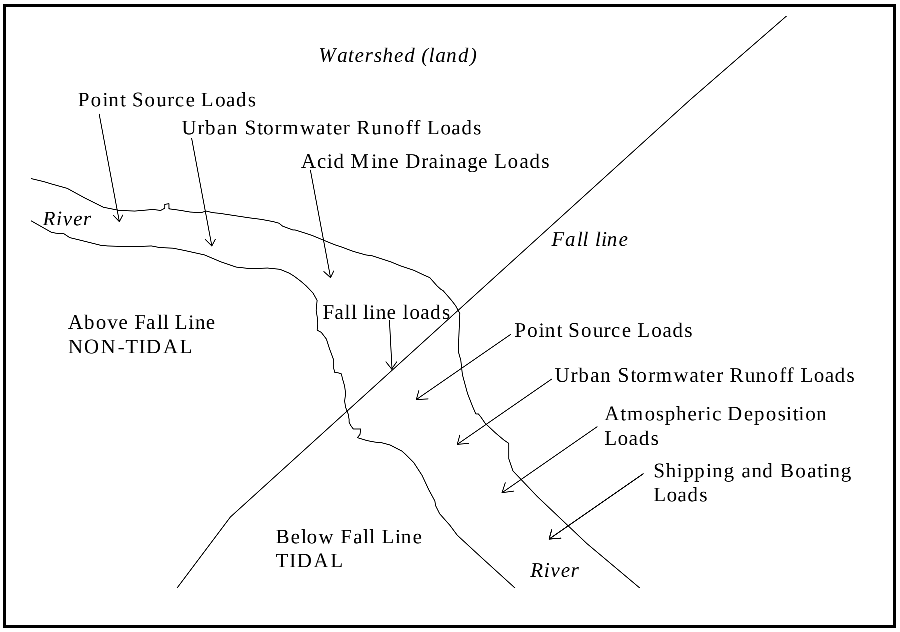


Figure 2. The sources of chemical contaminant loads to the Bay, above the fall line and below the fall line, reported in this inventory.

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:

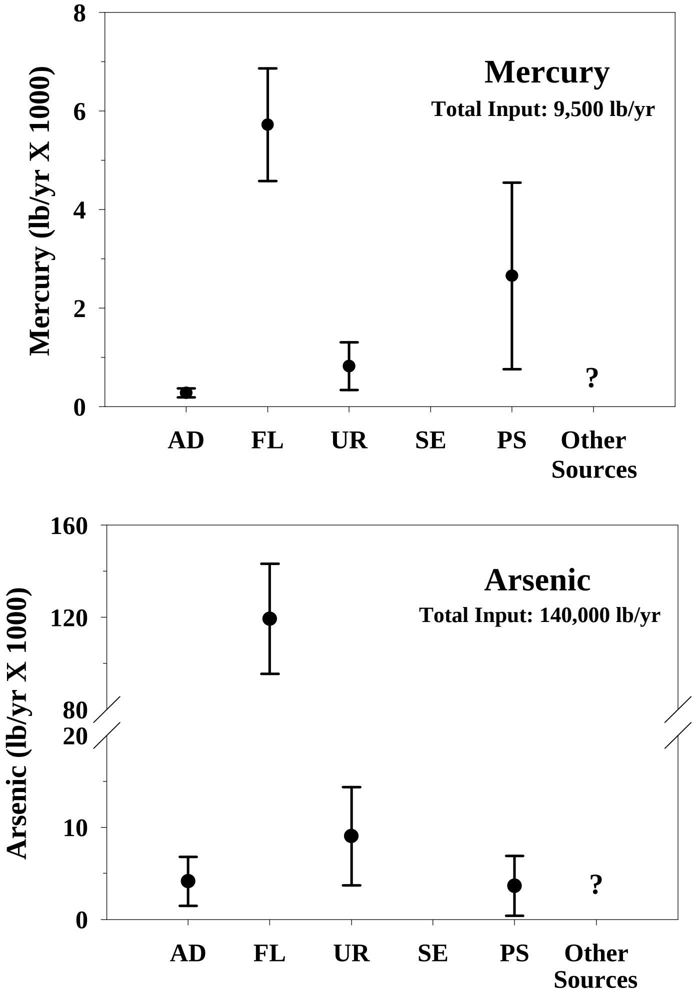
The 1999 inventory is an important step forward in the Bay Program's efforts to compile a comprehensive, high quality inventory of point and nonpoint source loads to the Bay. The Bay Program has made significant improvements to the previous 1994 inventory by increasing the sources quantified and improving 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

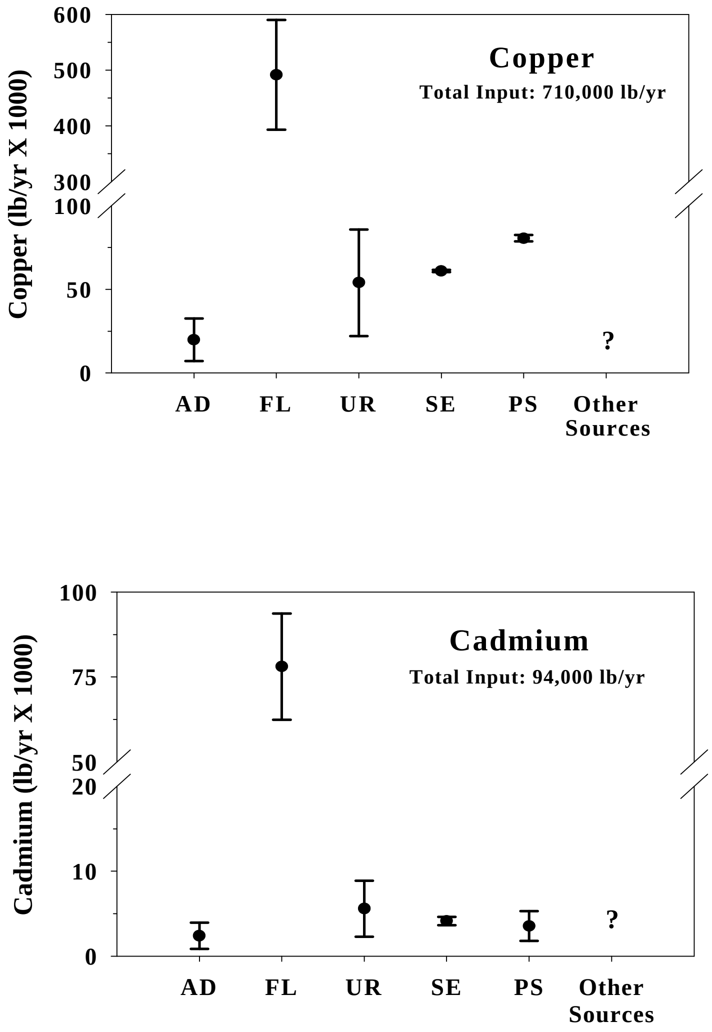
Sources of contaminants to the Bay and its tidal rivers vary by chemical and by land use and activities on the watershed. Through analysis of loadings data estimated using data collected between 1990 and 1997, some clear patterns are observed:

- **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.

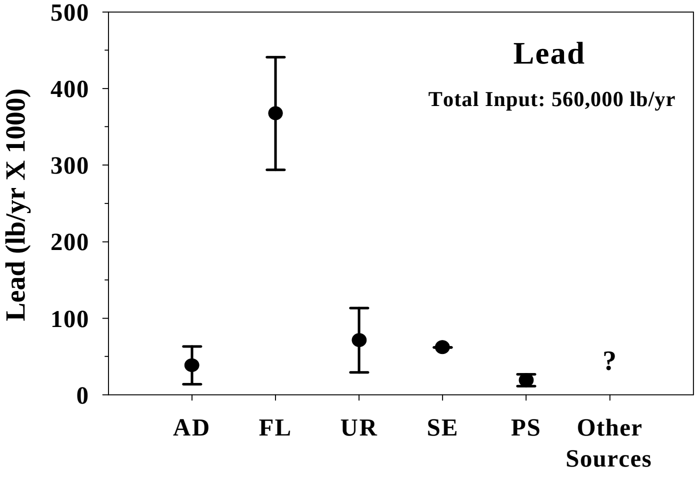
- **Point sources below the fall line account for a substantial load of metals, such as copper and mercury, to the entire Bay and its tidal rivers.** Point source loads of copper and mercury account for 11% and 28% of total loads respectively.

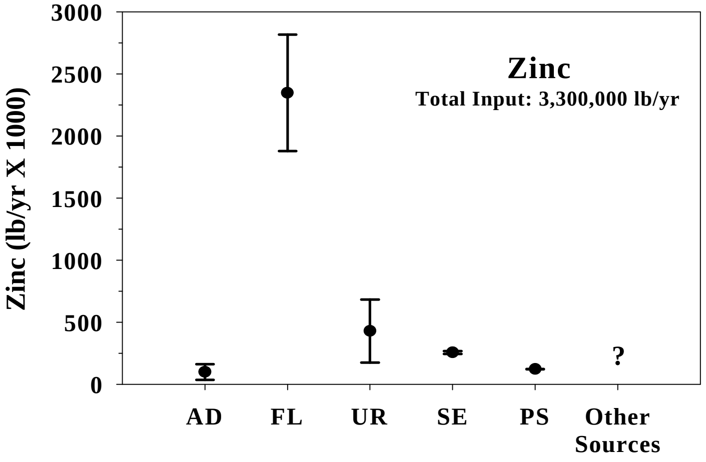


Total loads of mercury and arsenic to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

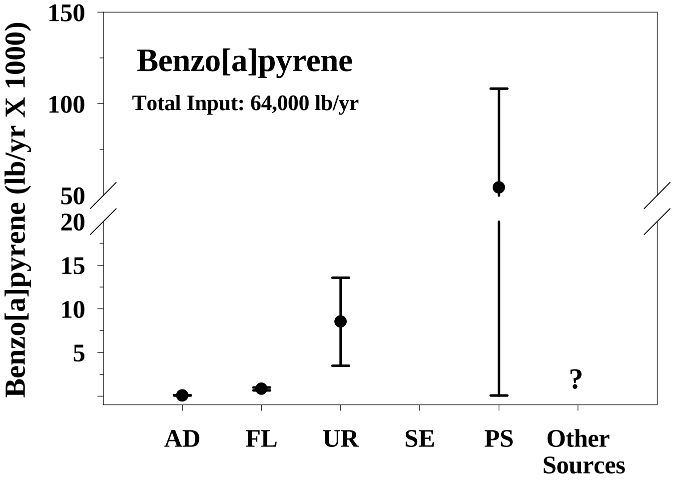




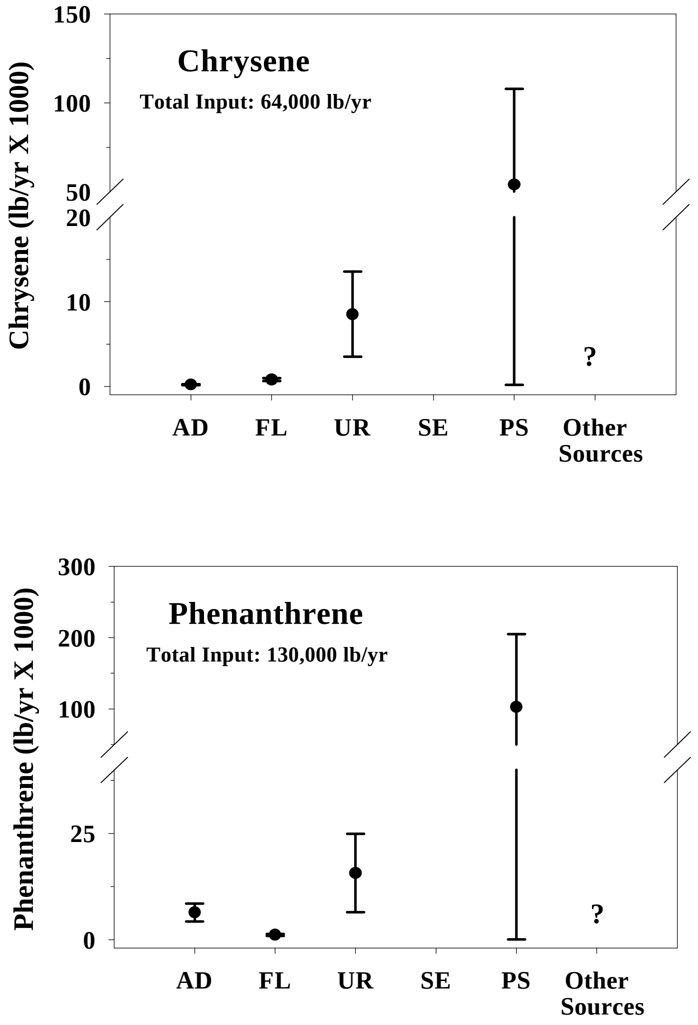
Total loads of lead and zinc to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric 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.

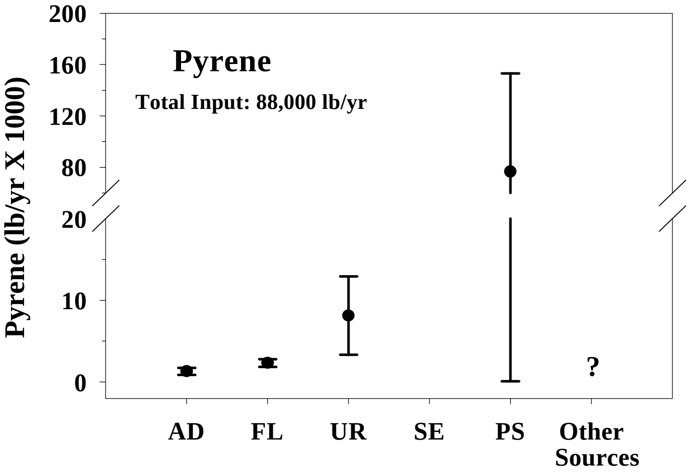
- **Urban runoff below the fall line is a substantial source of select organic contaminants (PAHs) to the Bay and tidal rivers.** Given that point source loads estimates are highly uncertain (as indicated by the large uncertainty bar in the figures), urban stormwater runoff is the most substantial known 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.



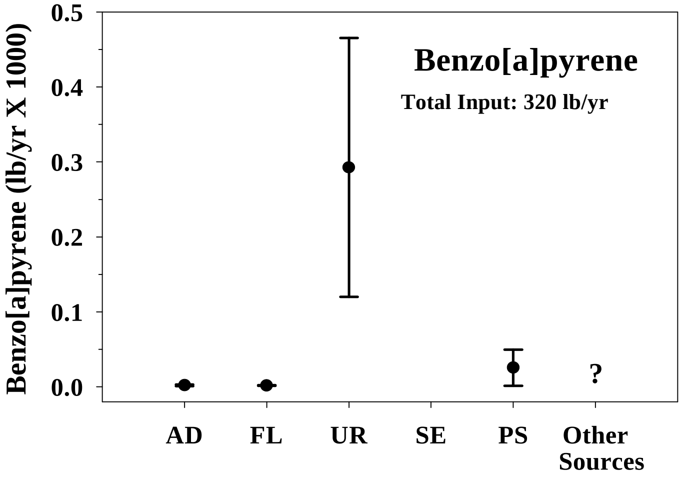
Total loads of the PAH benzo[a]pyrene to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff,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

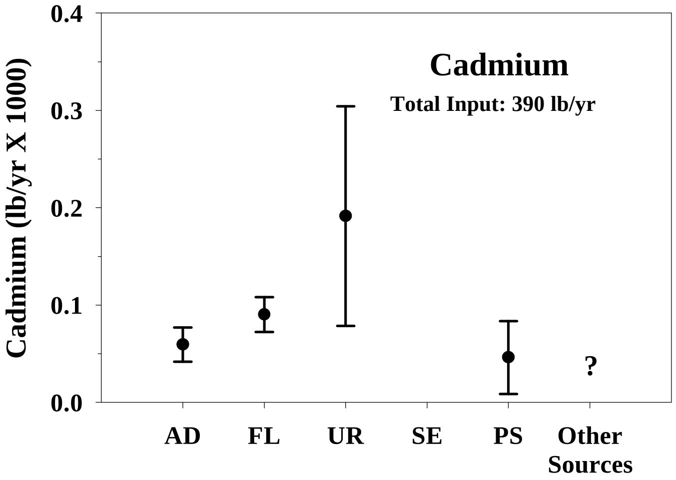


Total loads of pyrene to the tidal waters of the Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric deposition,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

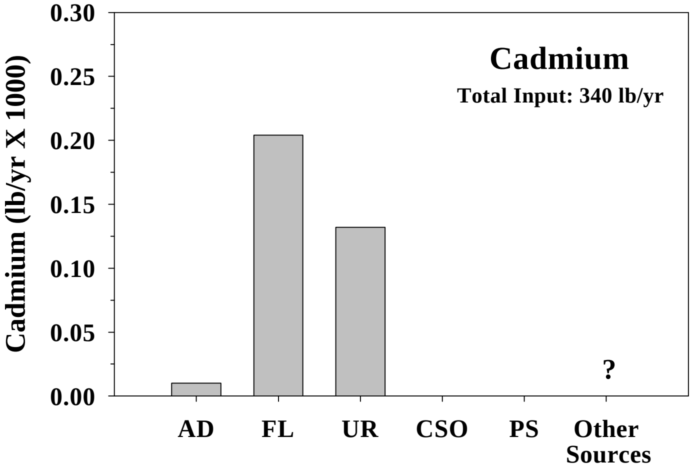


Total loads of benzo[a]pyrene to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosion (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric 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^2-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.

Acknowledgments

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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Table of Contents

V. Loadings

VI. The Fall Line

VII. Releases

LIST OF TABLES/FIGURES

Chapter 1 - Point Source Loadings

Chapter 2 - Urban Stormwater Loadings

Chapter 3 - Atmospheric Deposition Loadings

Chapter 4 - Shipping and Boating Loadings

Chapter 5 - Acid Mine Drainage Loadings

Chapter 6 - Fall Line Loadings

Chapter 7 - Pesticide Use

Chapter 8 - Relative Importance of Point and Non-point Sources to the Bay

Chapter 9 - Mass Balance of Chemical Contaminants within Chesapeake Bay

DESCRIPTION OF INVENTORY CHAPTERS

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 <u>reach</u> 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 <u>at</u> the fall line.
- ***Releases*** are estimates of the quantity of chemical contaminants <u>emitted</u> 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.

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 appendicies accompany this chapter of the Toxics Loading and Release Inventory document. These appendicies 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

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
1. NPDES FORM 2C & FORM A	Hard copy* NPDES Application forms (2c & A) [1]	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
2. NPDES DMR	A. NPDES DMR Reports from PCS [2]	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.	
3. VA TMP	TMP (Toxics Management Program) [3]	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.

[1] **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.

[2] **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.

[3] **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.

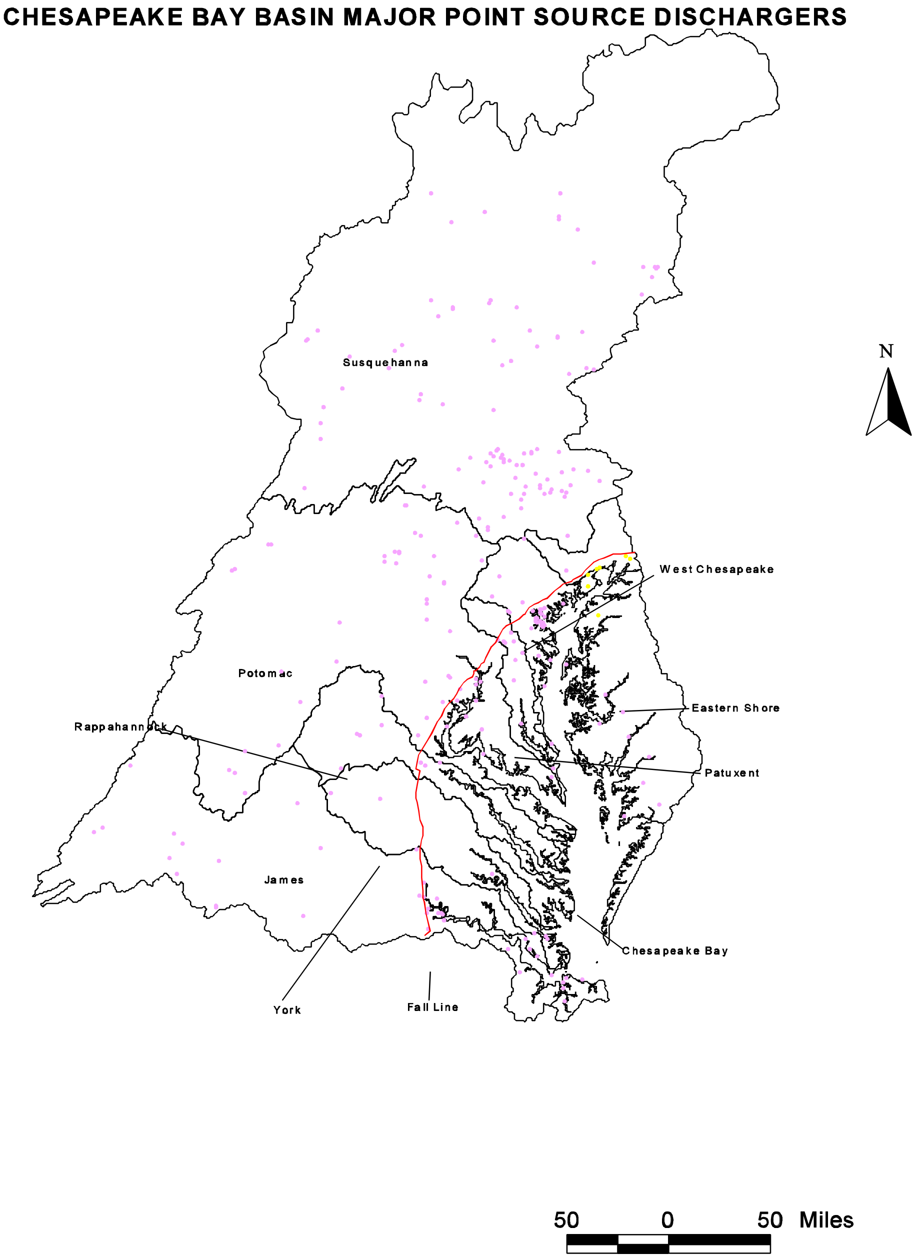


Figure 1.1. Chesapeake Bay Basin major point source dischargers.

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 vise 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 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.

Top 18 Chemicals with the highest loads

CHEMICAL	Loads* (lbs/year)
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 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.

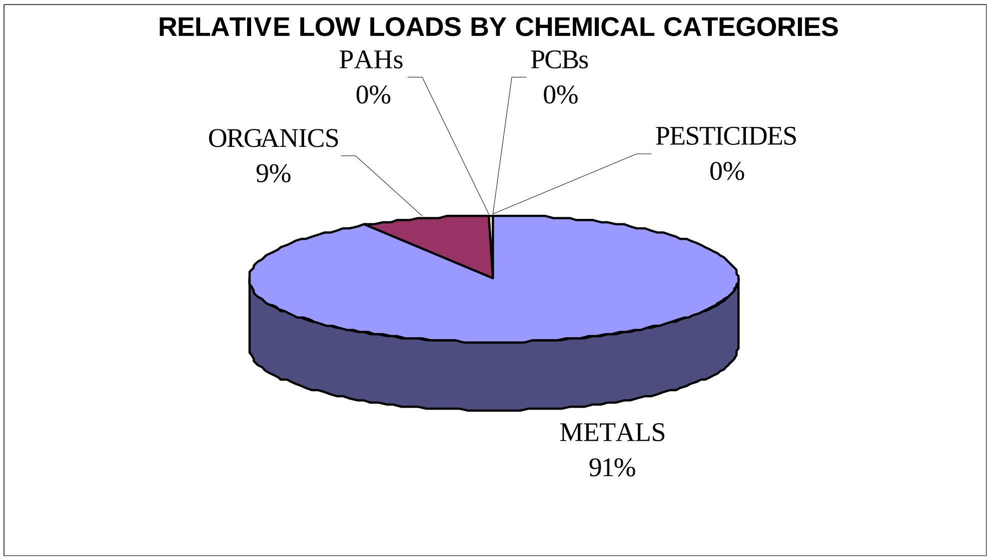


Figure 1.2. Relative Low Chesapeake Bay Basin point source loads by chemical category.

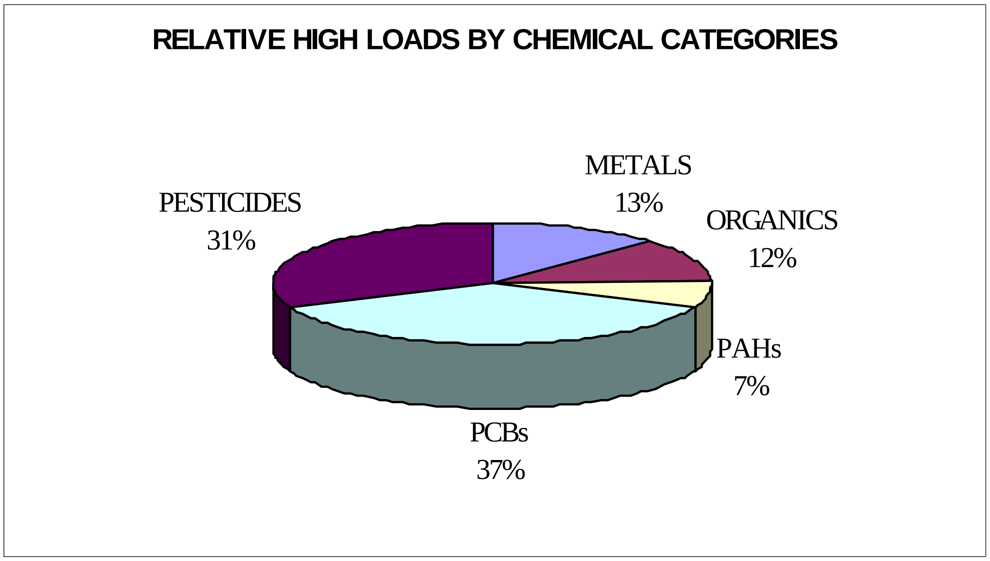


Figure 1.3. Relative High Chesapeake Bay Basin point source loads by chemical category.

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.

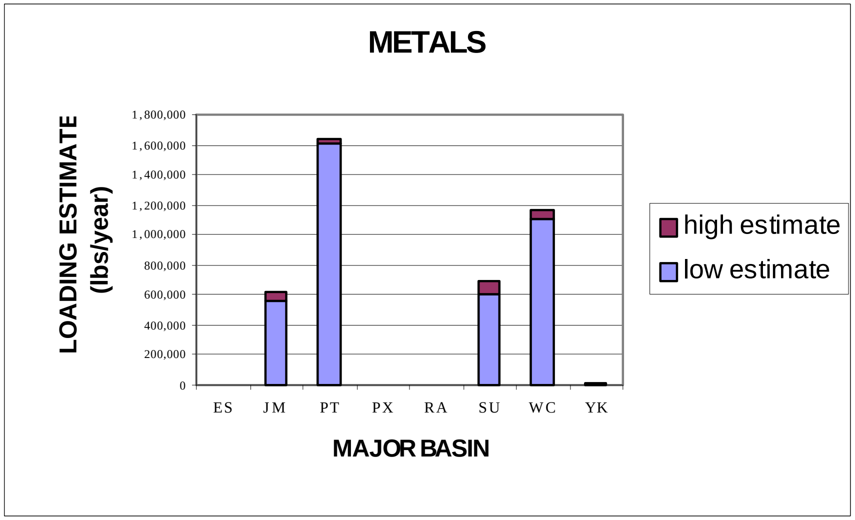


Figure 1.4. Loading estimates of metals by major basin**.**

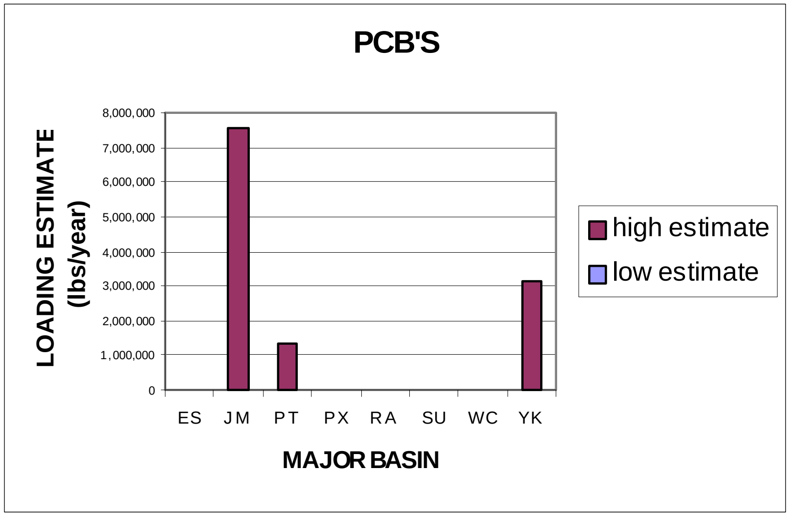


Figure 1.5. Loading estimates of PCB's by major basin.

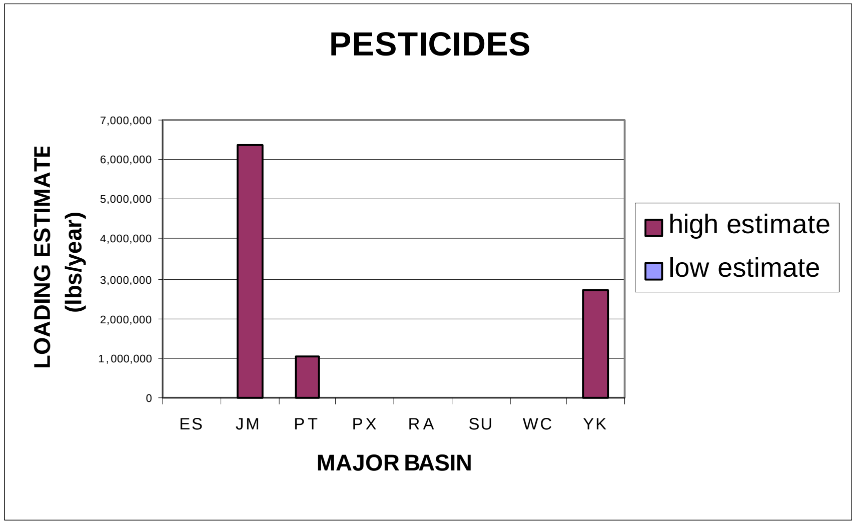


Figure 1.6. Loading estimates of pesticides by major basin**.**

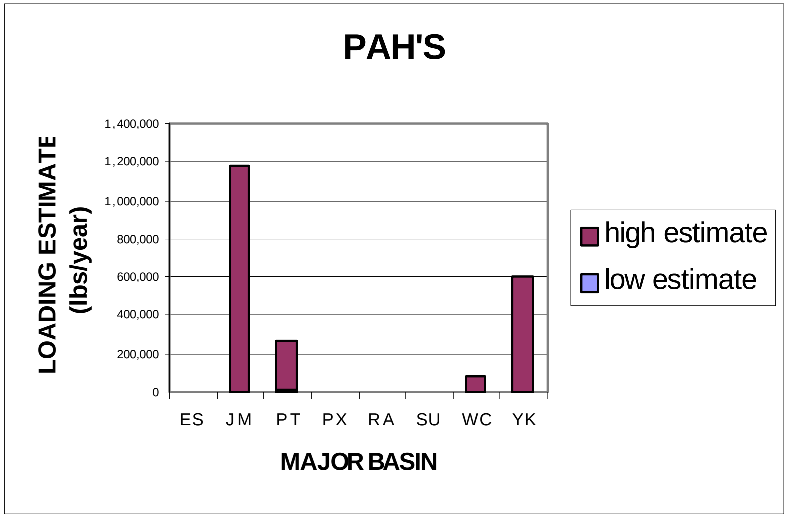
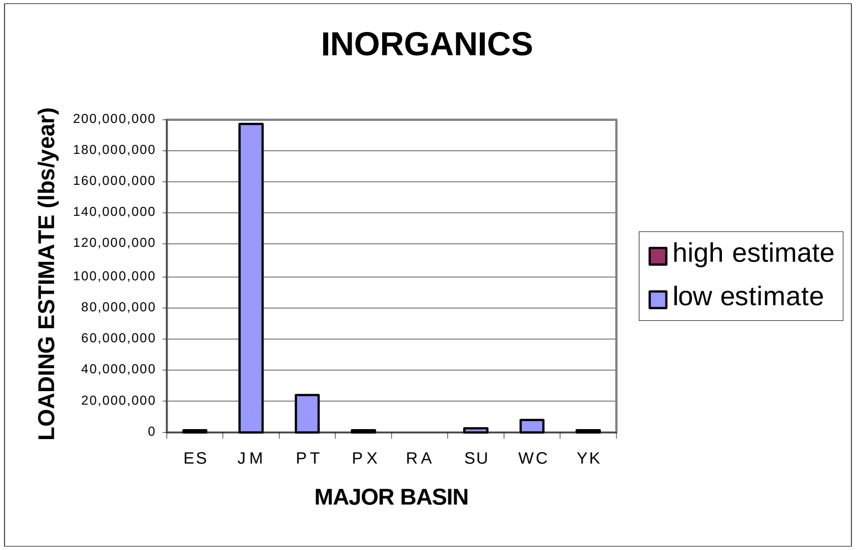


Figure 1.7. Loading estimates of PAH's by major basin.



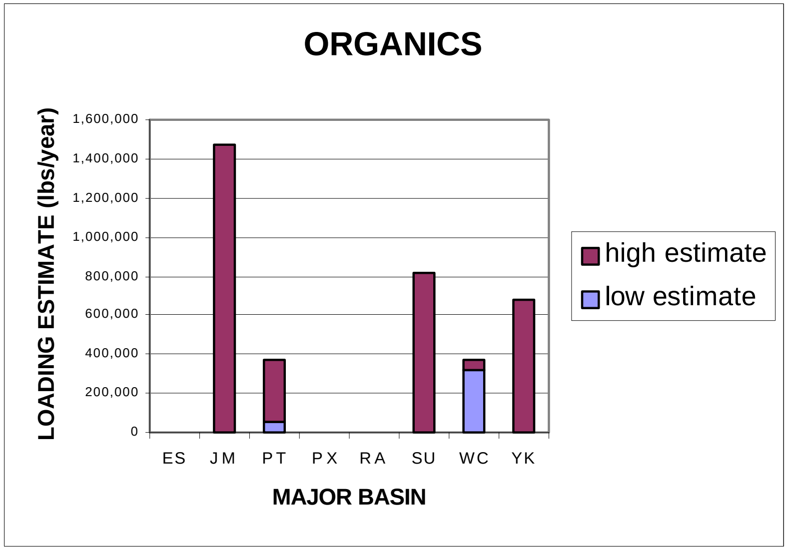


Figure 1.8. Loading estimates of inorganics by major basin.

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

  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 anaylses 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.

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

	TOTAL CHESAPEAKE BAY WATERSHED LOAD ESTIMATE (lbs/year)	
CHEMICAL	**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-METHYLNAPTHTHALENE	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

CHEMICAL	LOW	HIGH
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

	(No AFL for Eastern Shore)		**EASTERN SHORE BFL**		
# of facilities in estimate			10		10
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)**
2,4,6-TRICHLOROPHENOL					
2,4-DICHLOROPHENOL					
2,4-DIMETHYLPHENOL					
2,4-DINITROPHENOL					
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPTHTHALENE					
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

	(No AFL for Eastern Shore)		**EASTERN SHORE BFL**		
# of facilities in estimate			10		10
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)**
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

	(No AFL for Eastern Shore)		**EASTERN SHORE BFL**		
# of facilities in estimate			10		10
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)**
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

	JAMES RIVER AFL		**JAMES RIVER BFL**		
# of facilities in estimate	16		19		35
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)**
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-METHYLNAPTHTHALENE			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[GHI]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

	JAMES RIVER AFL		**JAMES RIVER BFL**		
# of facilities in estimate	16		19		35
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	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

	JAMES RIVER AFL		**JAMES RIVER BFL**		
# of facilities in estimate	16		19		35
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)**
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

	POTOMAC RIVER AFL		POTOMAC RIVER BFL		
# of facilities in estimate	41		14		55
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)**
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-METHYLNAPTHTHALENE	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

	POTOMAC RIVER AFL		**POTOMAC RIVER BFL**		
# of facilities in estimate	41		14		55
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	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

	POTOMAC RIVER AFL		**POTOMAC RIVER BFL**		
# of facilities in estimate	41		14		55
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)**
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

	(No AFL for Patuxent River)		PATUXENT RIVER BFL		
# of facilities in estimate			8		8
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)**
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-METHYLNAPTHTHALENE					
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

	(No AFL for Patuxent River)		**PATUXENT RIVER BFL**		
# of facilities in estimate			8		8
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					
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

	(No AFL for Patuxent River)		PATUXENT RIVER BFL		
# of facilities in estimate			8		8
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)**
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

	RAPPAHANNOCK AFL		**RAPPAHANNOCK BFL**		
# of facilities in estimate	5		3		8
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)**
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-METHYLNAPTHTHALENE					
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

	RAPPAHANNOCK AFL		RAPPAHANNOCK BFL		
# of facilities in estimate	5		3		8
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	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

	RAPPAHANNOCK AFL		**RAPPAHANNOCK BFL**		
# of facilities in estimate	5		3		8
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)**
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

	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
# of facilities in estimate	74		1		75
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)**
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-METHYLNAPTHTHALENE					
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

	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
# of facilities in estimate	74		1		75
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					
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

	SUSQUEHANNA, AFL		**SUSQUEHANNA, BFL**		
# of facilities in estimate	74		1		75
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)**
ZINC, DISSOLVED ZINC, TOTAL ZINC, TOTAL RECOVERABLE	358,509.13	71.50	38.17	0.01	358,547.30

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

	WEST CHESAPEAKE BASIN, AFL		WEST CHESAPEAKE BASIN, BFL		
# of facilities in estimate	6		27		33
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)**
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-METHYLNAPTHTHALENE					
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[GHI]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

	WEST CHESAPEAKE BASIN, AFL		**WEST CHESAPEAKE BASIN, BFL**		
# of facilities in estimate	6		27		33
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					
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

	WEST CHESAPEAKE BASIN, AFL		**WEST CHESAPEAKE BASIN, BFL**		
# of facilities in estimate	6		27		33
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)**
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

	YORK RIVER, AFL		**YORK RIVER, BFL**		
# of facilities in estimate	1		3		4
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)**
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-METHYLNAPTHTHALENE					
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[GHI]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

	YORK RIVER, AFL		YORK RIVER, BFL		
# of facilities in estimate	1		3		4
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	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

	YORK RIVER, AFL		**YORK RIVER, BFL**		
# of facilities in estimate	1		3		4
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)**
ZINC, DISSOLVED	0	0	1,413.38	2.66	1,413.38
ZINC, TOTAL			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

	(No AFL for Eastern Shore)		**EASTERN SHORE BFL**		
# of facilities in estimate			10		10
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)**
2,4,6-TRICHLOROPHENOL					
2,4-DICHLOROPHENOL					
2,4-DIMETHYLPHENOL					
2,4-DINITROPHENOL					
2-METHYL-4-CHLOROPHENOL					
2-METHYLNAPTHTHALENE					
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

	(No AFL for Eastern Shore)		**EASTERN SHORE BFL**		
# of facilities in estimate			10		10
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					
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

	(No AFL for Eastern Shore)		**EASTERN SHORE BFL**		
# of facilities in estimate			10		10
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)**
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

	JAMES RIVER AFL		**JAMES RIVER BFL**		
# of facilities in estimate	16		19		35
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)**
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-METHYLNAPTHTHALENE			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

	JAMES RIVER AFL		**JAMES RIVER BFL**		
# of facilities in estimate	16		19		35
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

	JAMES RIVER AFL		**JAMES RIVER BFL**		
# of facilities in estimate	16		19		35
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)**
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

	POTOMAC RIVER AFL		POTOMAC RIVER BFL		
# of facilities in estimate	41		14		55
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)**
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-METHYLNAPTHTHALENE	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

	POTOMAC RIVER AFL		**POTOMAC RIVER BFL**		
# of facilities in estimate	41		14		55
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	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

	POTOMAC RIVER AFL		**POTOMAC RIVER BFL**		
# of facilities in estimate	41		14		55
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)**
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 1.3l. Patuxent River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

	(No AFL for Patuxent River)		**PATUXENT RIVER BFL**		
# of facilities in estimate			8		8
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)**
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-METHYLNAPTHTHALENE					
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 1.3l. Patuxent River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

	(No AFL for Patuxent River)		**PATUXENT RIVER BFL**		
# of facilities in estimate			8		8
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					
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 1.3l. Patuxent River Basin high load estimates and percentage of total Chesapeake Bay Watershed load estimates

	(No AFL for Patuxent River)		**PATUXENT RIVER BFL**		
# of facilities in estimate			8		8
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)**
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

	RAPPAHANNOCK AFL		**RAPPAHANNOCK BFL**		
# of facilities in estimate	5		3		8
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)**
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-METHYLNAPTHTHALENE					
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

	RAPPAHANNOCK AFL		**RAPPAHANNOCK BFL**		
# of facilities in estimate	5		3		8
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	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

	RAPPAHANNOCK AFL		**RAPPAHANNOCK BFL**		
# of facilities in estimate	5		3		8
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)**
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

	SUSQUEHANNA, AFL		**SUSQUEHANNA, BFL**		
# of facilities in estimate	74		1		75
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)**
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-METHYLNAPTHTHALENE					
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

	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
# of facilities in estimate	74		1		75
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					
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

	SUSQUEHANNA, AFL		SUSQUEHANNA, BFL		
# of facilities in estimate	74		1		75
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)**
ZINC, DISSOLVED ZINC, TOTAL ZINC, TOTAL RECOVERABLE	358591.98	70.89	38.48	0.01	358,630.45

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

	WEST CHESAPEAKE BASIN, AFL		WEST CHESAPEAKE BASIN, BFL		
# of facilities in estimate	6		27		33
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)**
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-METHYLNAPTHTHALENE					
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

	WEST CHESAPEAKE BASIN, AFL		**WEST CHESAPEAKE BASIN, BFL**		
# of facilities in estimate	6		27		33
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					
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

	WEST CHESAPEAKE BASIN, AFL		WEST CHESAPEAKE BASIN, BFL		
# of facilities in estimate	6		27		33
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)**
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

	YORK RIVER, AFL		**YORK RIVER, BFL**		
# of facilities in estimate	1		3		4
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)**
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-METHYLNAPTHTHALENE					
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[GHI]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

	YORK RIVER, AFL		YORK RIVER, BFL		
# of facilities in estimate	1		3		4
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	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

	YORK RIVER, AFL		YORK RIVER, BFL		
# of facilities in estimate	1		3		4
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)**
ZINC, DISSOLVED	0	0	1,413.38	2.65	1,413.38
ZINC, TOTAL			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.

	AVERAGE LOAD ESTIMATES (LBS/YEAR)							
	DC		MD		VA		PA	
Chemical Substance	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-METHYLNAPTHTHALENE					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		
SOLUABLE			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[GHI]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	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
RECOVERABLE					6.44	6.44		
LEAD, DISSOLVED			121.27	573.27	945.98	6,473.58		
LEAD, TOTAL	3,283.47	3,283.47	3,358.48	17,546.72	5,309.11	27,346.92	4,200.06	5,460.01
RECOVERABLE			83.65	234.53	2,771.85	4,265.61		
MANGANESE, DISSOLVED					107,016.01	107,016.01		
MANGANESE, TOTAL			77,605.50	77,605.50	374,693.04	375,816.70	11,296.97	11,296.97
MERCURY, DISSOLVED					483.16	739.85		
MERCURY, TOTAL	0.16	1,971.01	474.76	857.25	204.10	1,225.57	4.62	1,596.96
MERCURY, TOTAL RECOVERABLE			0.00	3.78	234.61	951.03		
NAPHTHALENE			95.89	7,972.97	8,448.01	162,790.86	0.01	0.21
NICKEL, DISSOLVED					12,131.60	17,986.95		
NICKEL, TOTAL			17,003.17	30,697.18	12,075.28	19,009.53	3,522.14	13,710.69
NICKEL, TOTAL RECOVERABLE			206.79	311.85	2,099.98	5,986.71		
NITRITE PLUS NITRATE			5,194,752.43	5,202,118.08	511,435.00	515,972.88		
TOTAL	1,035,121.97	1,035,428.64	6,422,003.84	6,439,557.08	199,603,134.87	199,606,446.63	2,644,827.52	2,647,474.35
NITROGEN, NITRATE DISSOLVED			204,161.00	204,161.00				
TOTAL	11,501,718.58	11,501,718.58	2,419,834.20	2,419,834.20	3,069,691.83	3,087,051.52		
PCB 1221					0.00	1,173,074.17		
PCB 1232			0.00	18.43	0.00	1,904,281.19		
PCB 1242			0.00	20.31	0.00	1,904,248.17		
PCB 1254			0.00	38.47	0.00	1,393,281.10		
PCB-1016			0.00	20.31	0.00	1,904,205.27		
PCB-1248			0.00	22.20	0.00	1,904,007.79	0.00	0.00
PCB-1260			0.00	44.13	0.15	1,904,075.55		
PENTACHLOROBIPHENYL					0.00	97.73		

	AVERAGE LOAD ESTIMATES (LBS/YEAR)							
	DC		**MD**		**VA**		**PA**	
Chemical Substance	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.

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 it's 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.

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

Chemical	**Some Potential Urban Sources**
Aluminum	natural sources, coal combustion
Antimony	gasoline, paints, plastics
Arsenic	fossil fuel combustion, smelting, pesticides
Berylium	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 Esthers	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.

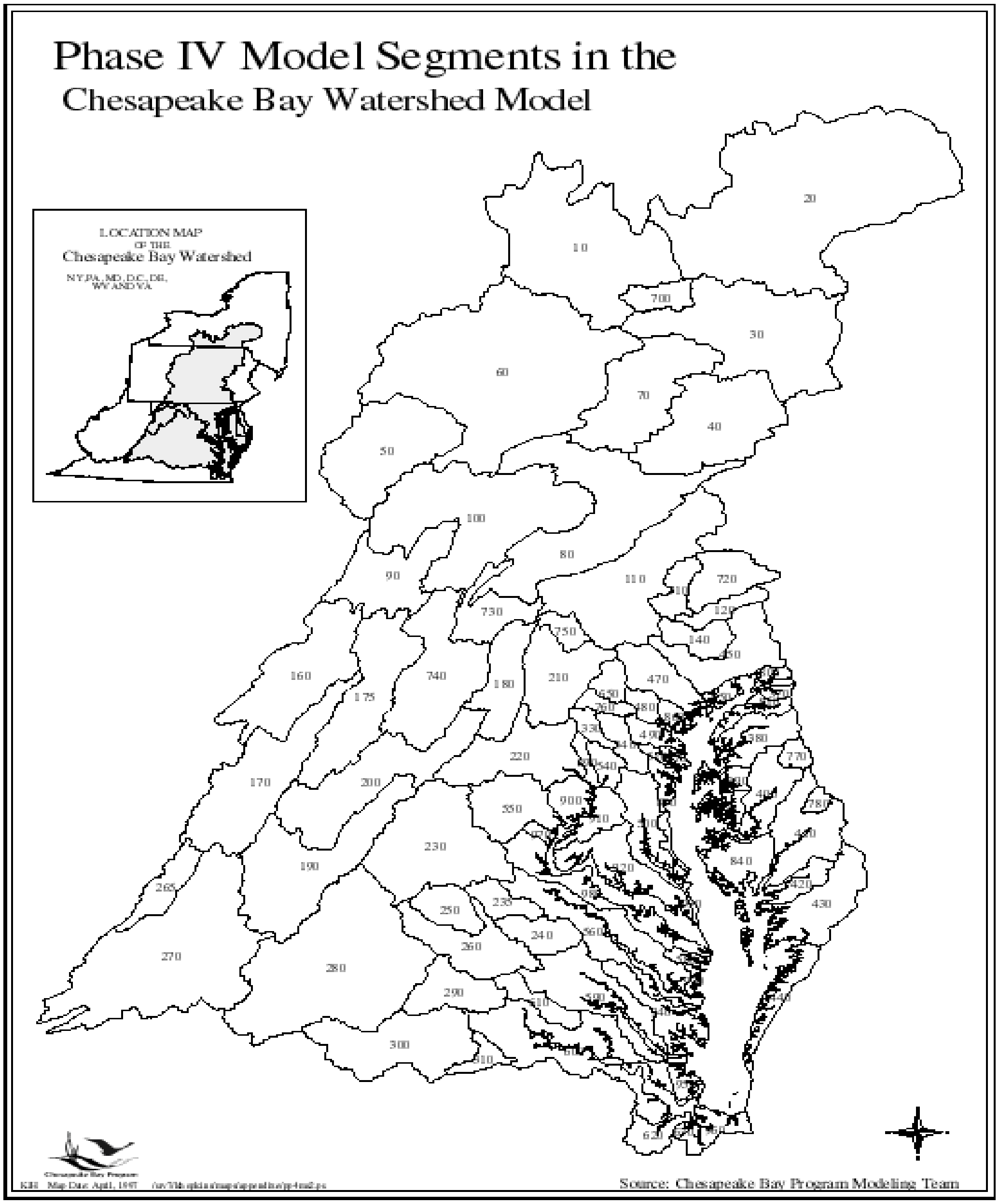
The Chesapeake Bay Watershed Model estimates runoff for 87 discrete modeling segments in the Bay basin (Figure 2.1), based on land use classifications developed from US EPA's 1990 Environmental Monitoring and Assessment (EMAP) and USGS's Geographic Information Retrieval and Analysis System (GIRAS) land 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 E.1.2



3

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 ±10% estimate of modeling error due to land use with the ±16% error from the interannual runoff variability, the uncertainty in the calculated runoff values is likely to be about ±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, ±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.

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

	Number of Stations Sampled By Predominant Land Use in Watershed[1]					
Jurisdiction	**Industrial**[2]	**Commercial**	**High Density Residential**	**Medium Density Residential**	**Low Density Residential**	**Other**[3]
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

[1] General predominant land use category, as reported by the jurisdictions.

[2] This category includes watersheds with predominantly industrial or light industrial/commercial land use.

[3] This category includes watersheds with some urban but predominantly agricultural or park land uses.

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[1]	357	96	26.9%	11	46
Toluene	358	4	1.1%	1	4
Phenol	356	3	0.8%	2	3
Acenaphthene[2]	357	1	0.3%	1	1
Anthracene	358	2	0.6%	1	2
Benzo(a)anthracene[2,3]	358	4	1.1%	3	4
Benzo(a)pyrene[2,3]	358	3	0.8%	2	3
3,4-benzofluoranthene	345	6	1.7%	4	5
Benzo(ghi)perylene[2]	358	2	0.6%	1	2
Benzo(k)fluroanthene	358	3	0.8%	2	3
Bis(2-chloroethoxy)methane	358	3	0.8%	2	3
Bis(2-ethylhexyl)phthalate[1]	358	54	15.1%	11	36
Chrysene[2,3]	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[3,4]	357	16	4.5%	12	8
Fluorene[2]	358	3	0.8%	3	3
Indeno(1,2,-cd)pyrene[2]	358	1	0.3%	1	1
Phenanthrene[4]	353	11	3.1%	6	9
Pyrene[2]	358	16	4.5%	6	12
Antimony	337	22	6.5%	7	15
Arsenic[2,5]	357	119	33.3%	15	62
Berylium	337	36	10.7%	9	27
Cadmium[2,3]	361	124	34.3%	15	64
Chromium[2,3]	341	184	54.0%	17	87
Copper[3,4]	361	318	88.1%	19	112
Lead[3,4]	361	241	66.8%	17	97
Mercury[2,3]	338	18	5.3%	9	16
Nickel[2]	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[2,5]	361	5650	97.2%	20	119

[1] Common laboratory contaminant, suspect data.
[2] Draft Revised Chemicals of Potential Concern List
[3] 1990 Toxics of Concern List
[4] Draft Revised Toxics of Concern List
[5] 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).

Chemical	Min. Detected Value	Max. Detected Value	Geometric Mean of Detected Values	Average Available Detection Limit	Lower Geometric Mean	Upper Geometric Mean	EMC (Middle Geometric Mean)
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)fluroanthene	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
Berylium	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.

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).

Chemical	**Current Study EMC**	**Previous Load Estimate EMC**[1]
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
Berylium	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

[1] 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

Chemical	**Chesapeake Bay Total**			**Susquehanna**	**Western Shore MD**			**Eastern Shore MD**	**Patuxent**			**Potomac**		
	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 10^7	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)fluroanthene	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
Berylium	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)fluroanthene	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
Berylium	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

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

Chemical	**Current Study Total Load (Kg/yr)**	**Previous Study Total Load[1] (Kg/yr)**
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)fluroanthene	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
Berylium	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

[1] 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.

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.

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 µm diameter) particles to gravitational settling of large (>10 µm) 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^{c}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 ($F_{i,wet}$, µg/m^2-year) at a site are calculated as the product of volume-weighted mean chemical contaminant concentrations measured in precipitation ($C_{i,ppt}$, µg/m^3) and the corresponding precipitation amount (P, m/year):

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

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 (g/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 agrichemicals 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 agrichemicals 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 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_{dry}, µg/m^2-year) as the product of measured ambient aerosol-associated contaminant concentrations (C_{aero}, µg/m^3) and a chemical-specific and meteorological-averaged dry deposition velocity (V_d, m/year):

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

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^{c}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_{OL}s) 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^{c}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 association 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 ±10% and ±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)

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

and gas phase (C_a) concentrations, accounting for H. Total propagated variance [σ^2(F)] is the linear combination of the weighted contribution of the variances (σ^2) of the mass transfer coefficient, H, and measured concentrations. The σH 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 uncertainly 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 ± 139 ng/m^2-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 x 10^{10} 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 ±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 character dry aerosol deposition. This might be done in collaboration with USEPA's $PM_{2.5}$ 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 TLRIs 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.

Chemical	Dates	Location	Wet	Dry Aerosol	Gas Exchange	Reference
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

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).

Basin	**Surface Water Area (10^6 m^2)**	**Percent Urban**
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 (μg/m2-year) to the Chesapeake Bay.

	Wet Deposition(1)		Dry Aerosol Deposition(2)		Gas Exchange(3)		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]fluoranthane	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]pryene	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(4)	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

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^2)	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]fluoranthane	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]pryene	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^2)	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]fluoranthane	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]pryene	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^2)	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]fluoranthane	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]pryene	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^2)	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]fluoranthane	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]pryene	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.

	Percent Urban				
	0%	**5%**	**10%**	**20%**	**30%**
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]fluoranthane	61	70	79	98	116
Benzo[k]fluoranthene	39	45	51	63	74
Benzo[e]pryene	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

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 anitfoulant 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” 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[1]		
Benzo[a]pyrene			[1]		
Cadmium			Cadmium		
Chlordane	Chlordane				
Chromium			Chromium		
Chrysene			Chrysene		
Copper	Copper				
		Dieldrin	Dieldrin		
					Diflubenzuron[3]
		Fenvalerate			Fenvalerate
Fluoranthene	Fluoranthene				
Lead	Lead				
Mercury			Mercury		
		Metolachlor			Metolachlor
Naphthalene	Naphthalene				
			Nickel		
		Permethrin			Permethrin
	Phenanthrene				
PCBs	Arochlor 1260		Other PCBs[2]		
			Pyrene		
Tributyltin (TBT)	Tributyltin (TBT)				
		Toxaphene			Toxaphene
		Zinc	Zinc		

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

[1] 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.

[2] Other PCBs include: PCB cogeners 126 and 169, PCB Arochlors 1016, 1232, 1242, 1248, pentachlorobiphenyls, tetrachlorobiphenyls, and polychlorinated biphenyl.

[3] 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
NAPTHALENE (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
NAPTHALENE (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
NAPTHALENE (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
NAPTHALENE (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

	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
FUEL, ROCKET	LBS	49.7				49.7					
COSTIC SODA SOLUTION	GAL	43.0							42.9		0.1
NITROGEN, LIQUEFIED	GAL	42.9							42.9		
BILGE WATER WITH RESIDUAL OIL	GAL	38.6		7.7	0.4				30.4		
OIL, FUEL: F-76	GAL	35.9							35.9		
BATTERY, ATON	LBS	32.1							2.1		30.0
PAINT, OIL BASED	GAL	28.9	2.1	2.4		7.1			16.6		0.6
OIL, MISC: PETROLEUM DISTILLATE	GAL	28.6							28.6		
GASOLINE	GAL	24.6		20.0		3.6			.0.7	0.3	
OIL, FUEL: INTERMEDIATE (IFO 180)	GAL	22.6		9.7					12.9		
ASPHALT BLENDING STOCKS: ROOFERS FLUX	GAL	21.4		21.4							
FUEL, JET: JP-8	GAL	20.1		0.1				15.0	5.0		
OIL, FUEL: NO. 1-D	GAL	19.1	0.4	6.1	1.4						11.1
PARRAFIN/OLEFIN WAX/ NON-REGULATED/NON-HAZARD	GAL	19.0		4.3				0.3	13.4		1.0
HYDROCHLORIC ACID	GAL	16.1				14.3			1.9		
FUEL, MARINE DIESEL	GAL	16.0		1.4					14.6		
OIL, FUEL: NO. 1	GAL	15.9		12.9	0.1				2.9		
POLLEN	LBS	15.7							15.7		
2-2 BUTOXY ETHOXI	LBS	15.0									15.0
POTASSIUM HYDROXIDE	GAL	14.3		14.3							
LATEX, LIQUID NATURAL	GAL	12.9		11.4					1.4		
DETERGENT/DEGREASER	GAL	12.1	0.3	6.7				2.9	2.3		
TAR BALLS	GAL	10.6						0.1	5.1		5.3
HYDROGEN PEROXIDE	GAL	10.0								10.0	
ARSENIC TRIOXIDE	GAL	10.0		10.0							
OIL, HOME HEATING	GAL	10.0		5.7							4.3
OIL, MISC: MINERAL	GAL	8.6		5.0					3.6		
PRESERVATIVE	GAL	8.1							8.1		
LEAD SULFATE	LBS	8.0							5.9		2.1

	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		
DICHLOROMONOFLUOROMETHANE	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
CHLORINE SOLUTION	LBS	1.7							1.7		
PAINT, LATEX	GAL	1.6							1.6		
OIL, EMULSIFIED	GAL	1.4							1.4		
SOAP	GAL	1.4									1.4
G BASE	GAL	1.4		1.4							
DFM	GAL	1.4							1.4		
OIL, BLACK	GAL	1.4							1.4		
OIL, GAS: DESULFURIZED	GAL	1.4						1.4			
CHROMIC ANHYDRIDE	LBS	1.1		1.1							
OIL, EDIBLE: FISH	GAL	1.0		1.0							
FLOCOAT	GAL	0.9							0.9		
OIL, EDIBLE: SOYA BEAN	GAL	0.9							0.9		
OIL, EDIBLE: VEGETABLE	GAL	0.9		0.3					0.6		
GASOLINE BLENDING STOCKS: ALKYLATES	GAL	0.7		0.7							
OIL, FUEL: NAVY SPECIAL	GAL	0.7						0.7			
OIL, FUEL: INTERMEDIATE 380 INNERMIX	GAL	0.7		0.7							
RC250	GAL	0.7						0.7			
COPPER, SOFT	GAL	0.7						0.7			
TURPENTINE	GAL	0.7							0.7		
CREOSOTE (COAL TAR)	GAL	0.7							0.7		
OIL, TERRESTIC	GAL	0.6		0.6							
PHENOL	LBS	0.6							0.6		
BUTYL CARBITOL	LBS	0.6							0.6		
HYDRAZINE	GAL	0.4			0.4						
OIL, MISC: SPRAY	GAL	0.3		0.1		0.1					
ANTI-FREEZE	GAL	0.3							0.3		
DREDGE SPOILS	GAL	0.3							0.3		
GREASE, MISC.	GAL	0.3		0.3							
OIL, MISC: RESIN	GAL	0.3							0.1		0.1

	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			
NAPTHALENE (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		
DICHLOROMONOFLUOROMETHANE	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			
NAPTHALENE (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		

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 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.

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.

Stream Name	**Miles Degraded**
Upper Susquehanna River Subbasin	
Tioga River	3
Morris Run	1
Fall Brook	2
Long Valley Run	1.6
Upper Central Susquehanna River Subbasin	
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
Lower Susquehanna River Subbasin	
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

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)**
Lower Susquehanna River Subbasin	
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
Upper West Branch Susquehanna River Subbasin	
Sinnemahoning Creek	15.8
Bennett Branch Sinnemahoning Cr.	66.6
Dents Run	6.5
Trout Run	1
Spring Run	1.7
West Creek	12

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)**
Upper West Branch Susquehanna River Subbasin (cont'd)	
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

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)**
Upper West Branch Susquehanna River Subbasin (cont'd)	
Dutch Run	1.3
Brubaker Run	2
Birch Island Run	6.2
Little Birch Island Run	4.3
Amos Branch	1.6
Upper West Branch Susquehanna River Subbasin	
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
Central West Branch Susquehanna River Subbasin	
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

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)**
Central West Branch Susquehanna River Subbasin (cont'd)	
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
Lower West Branch Susquehanna River Subbasin	
Red Run	13.4
West Branch Susquehanna R.	3
Upper Juniata River Subbasin	
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.

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**
Northern Anthracite Coal Field							
Lackawanna River	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
(in-stream at mouth)	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
Eastern Middle Anthracite Coal Field							
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).

Tributary	Date	Flow	Condition	Sulfates	Iron	Manganese	Aluminum
Western Middle Anthracite Coal Field							
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	
Southern Anthracite Coal Field							
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.

Tributary	Date	Flow	Condition	Sulfates	Iron	Manganese	Aluminum	Zinc
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.

Tributary	**Date**	**Flow**	**Condition**	**Sulfates**	**Iron**	**Manganese**	**Aluminum**	**Zinc**
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).

Tributary	Date	Flow	Condition	Sulfates	Iron	Manganese	Aluminum	Zinc
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 Randolph Lake	1988-1989	73.1	Low	93,352	550	678	1,370	
	1988-1989	974.3	High	412,115	3,472	2,474	5,226	

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 FLTM 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 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.

Calendar Year	**Tributaries Monitored**	**Sampling Frequency**	**Constituents**
1992	Susquehanna, Potomac, and James	Monthly: Feb. - June Bimonthly: July - Jan. + major storms	metals + organics (USGS)[a]
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	Biweekly: Feb. - July Monthly: Aug.- Dec. + major storms	metals + organics
	Susquehanna, Potomac, James, Patuxent, Choptank, Nanticoke, Pamunkey, Mattaponi, Rappahannock	Spring and Fall synoptic	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)

[a] 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.

Organonitrogen & Organophosphorus Pesticides	**1992**	**1993**	**1994**	**1995**	**1996**
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.

Polycyclic Aromatic Hydrocarbons	**1992**	**1993**	**1994**	**1995**	**1996**
Naphthalene (Nap)[a]	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

[a] PAH abbreviations; X, constituent monitored; ns, not sampled.

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

Organochlorines	**1992**	**1993**	**1994**	**1995**	**1996**
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
$\overline{q_{ij}}$ = mean daily discharge (m^3/s) on ith day of jth period (base flow)
$\overline{q_{kl}}$ = mean daily discharge (m^3/s) on kth day of lth storm
c_j = concentration (dissolved + particulate) of constituent (kg/m^3) in jth period
c_{kl} = concentration (dissolved + particulate) of constituent (kg/m^3) on kth day of lth storm
t_{ij} = hours of base flow on ith day of jth period
t_{kl} = hours of storm flow on kth day of lth storm
n_j = 0.5 number of days in jth 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.

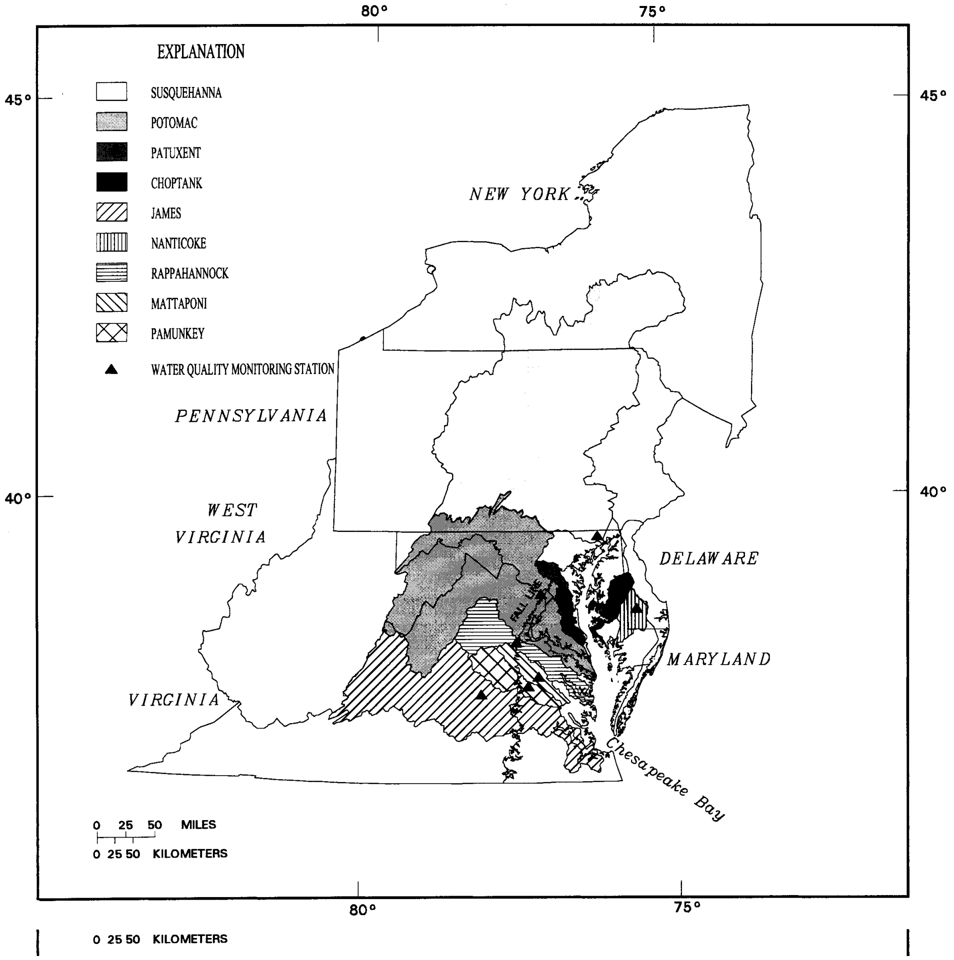

Figure 6.1. Map of Chesapeake Bay region showing nine watersheds monitored in 1994 synoptic study. (Map provided courtesy of the USGS in Baltimore, MD.)

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-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 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^3/s, 1,494 m^3/s, 1,464 m^3/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.

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

Organonitrogen & Organophosphorus Pesticides	Estimation Method	3/92-2/93 AFL	2/93-1/94 AFL	2/94-1/95 AFL
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.

Organonitrogen & Organophosphorus Pesticides	Estimation Method	3/92-2/93 AFL	2/93-1/94 AFL	2/94-1/95 AFL
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.

Organonitrogen & Organophosphorus Pesticides	**Estimation Method**	**3/92-2/93 AFL**	**2/93-1/94 AFL**	**2/94-1/95 AFL**
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.

Polycyclic Aromatic Hydrocarbon	**Estimation Method**	**3/92-2/93 AFL**	**2/93-1/94 AFL**	**2/94-1/95 AFL**
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

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

Polycyclic Aromatic Hydrocarbon	**Estimation Method**	**3/92-2/93 AFL**	**2/93-1/94 AFL**	**2/94-1/95 AFL**
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.

Polycyclic Aromatic Hydrocarbon	**Estimation Method**	**3/92-2/93 AFL**	**2/93-1/94 AFL**	**2/94-1/95 AFL**
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.

Organochlorines	**Estimation Method**	**3/92-2/93 AFL**	**2/93-1/94 AFL**	**2/94-1/95 AFL**
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	-	-

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

Organochlorines	**Estimation Method**	**3/92-2/93 AFL**	**2/93-1/94 AFL**	**2/94-1/95 AFL**
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.

Organochlorines	**Estimation Method**	**3/92-2/93 AFL**	**2/93-1/94 AFL**	**2/94-1/95 AFL**
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	-	-	-

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[a]	Estim. Method 1993	Loads 2/93-1/94 AFL[a]	Estim. Method 1994	Loads 2/94-1/95 AFL[b]
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

[a] Loads determined from total recoverable concentrations except for A1 loads for 1992 and 1993 in which they were determined from dissolved (only) concentrations.

[b] Loads determined from the sum of dissolved and particulate concentrations.

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

Trace Metals	Estim. Method 1992	Loads 3/92-2/93 AFL[a]	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		-		-

[a] 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[a]**	**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		-		-

[a] Loads determined from total recoverable concentrations except for A1 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

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.

	Pam	**Mat**	**Jam**	**Rap**	**Pot**	**Chop**	**Nant**	**Pat**	**Sus**
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.

	Pam	**Mat**	**Jam**	**Rap**	**Pot**	**Chop**	**Nant**	**Pat**	**Sus**
MN[a]	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

[a] Refer to Table 3 for PAH abbreviations.

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.

	Pam	**Mat**	**Jam**	**Rap**	**Pot**	**Chop**	**Nant**	**Pat**	**Sus**
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.

	Pam	**Mat**	**Jam**	**Rap**	**Pot**	**Chop**	**Nant**	**Pat**	**Sus**
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
α-BHC	0.0002	0.0002	0.0068	0.0045	0.25	0.0021	0.0024	0.0013	0.311
β-BHC	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4
γ-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
γ-Chlordane	0.0025	0.0032	0.038	0.014	0.1793	0.0016	0.0043	0.0002	0.97
α-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

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.

	Pam	**Mat**	**Jam**	**Rap**	**Pot**	**Chop**	**Nant**	**Pat**	**Sus**
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
α-BHC	<1e-4	<1e-4	0.0005	0.0001	0.0012	0.0002	<1e-4	0.0002	0.046
β-BHC	<1e-4	<1e-4	<1e-4	0.0003	<1e-4	<1e-4	<1e-4	<1e-4	<1e-4
γ-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
γ-Chlordane	0.0001	0.0011	0.026	0.0028	0.023	<1e-4	<1e-4	0.0083	0.062
α-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.

	Pam	**Mat**	**Jam**	**Rap**	**Pot**	**Chop**	**Nant**	**Pat**	**Sus**
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.

	Pam	**Mat**	**Jam**	**Rap**	**Pot**	**Chop**	**Nant**	**Pat**	**Sus**
Al	3860	548	966	390	17800	14.6	46.6	186	126000
Cd	na[a]	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

[a] 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[1].

Chemical Name	**Pounds Active Ingredient (AI) (000)**				**Multiple Acres Treated[2] (000)**				**Typical Rate Pounds AI/Acre/Year**			
	MD	**PA**	**VA**	**TOTAL[3]**	**MD**	**PA**	**VA**	**TOTAL[3]**	**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[3]	2,041	3,982	1,726	7,749	2,013	3,376	1,434	6,823	N/A	N/A	N/A	N/A

[1] -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.

[2] - Includes multiple applications of a given pesticide on the same acre in the same year.

[3] - 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[1].

Chemical Name	**Pounds Active Ingredient (AI) (000)**				**Multiple Acres Treated[2] (000)**				**Typical Rate Pounds AI/Acre/Year**			
	MD	**PA**	**VA**	**TOTAL[3]**	**MD**	**PA**	**VA**	**TOTAL[3]**	**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[3]	1,670	3,676	1,140	6,486	1,531	3,064	906	5,501	N/A	N/A	N/A	N/A

[1] - 1,985,000 acres of corn were grown in the watershed in 1996 (MD - 495,000; PA - 1,150,000; VA - 340,000)

[2] - Includes multiple applications of a given pesticide on the same acre in the same year.

[3] - 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[1].

Chemical Name	**Pounds Active Ingredient (AI) (000)**				**Multiple Acres Treated[2] (000)**				**Typical Rate Pounds AI/Acre/Year**			
	MD	**PA**	**VA**	**TOTAL[3]**	**MD**	**PA**	**VA**	**TOTAL[3]**	**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[3]	13	45	12	70	22	72	18	112	N/A	N/A	N/A	N/A

[1] - 740,000 acres of alfalfa were grown in the watershed in 1996 (MD - 60,000; PA - 600,000; VA - 80,000)
[2] - Includes multiple applications of a given pesticide on the same acre in the same year.
[3] - 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.

Table 7.4. Pesticide Usage on Soybeans in the Chesapeake Bay Watershed by Chemical Name, 1996[1].

Chemical Name	**Pounds Active Ingredient (AI) (000)**				**Multiple Acres Treated/2 (000)**				**Typical Rate Pounds AI/Acre/Year**			
	MD	**PA**	**VA**	**TOTAL[3]**	**MD**	**PA**	**VA**	**TOTAL[3]**	**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[3]	487	311	643	1,441	652	352	723	1,726	N/A	N/A	N/A	N/A

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

[2] - Includes multiple applications of a given pesticide on the same acre in the same year.

[3] - 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[1].

Chemical Name	**Pounds Active Ingredient (AI) (000)**				**Multiple Acres Treated[2] (000)**				**Typical Rate Pounds AI/Acre/Year**			
	MD	**PA**	**VA**	**TOTAL[3]**	**MD**	**PA**	**VA**	**TOTAL[3]**	**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[3]	59	70	55	183	497	177	360	1,034	N/A	N/A	N/A	N/A

[1] - 990,000 acres of small grains were grown in the watershed in 1996 (MD - 300,000; PA - 380,000; VA - 310,000)
[2] - Includes multiple applications of a given pesticide on the same acre in the same year.
[3] - 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.

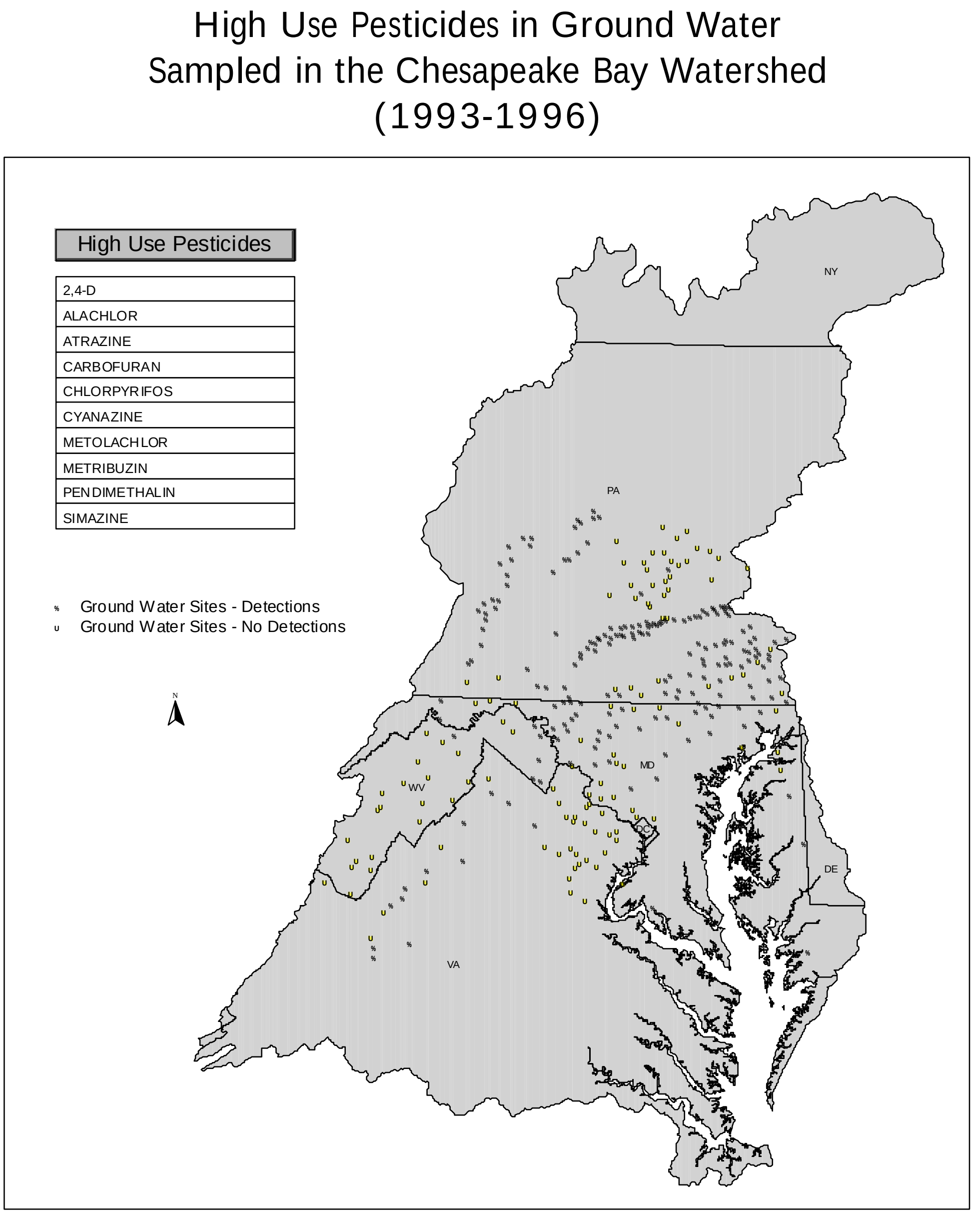
Note: These data are from USGS's Mid-Atlantic Assessment (MAIA) project: pesticide concentrations from 463 surface water sites. Only data from 1993-1996 within the Chesapeake Bay Watershed were used for this analysis. These data are referenced in the USGS Water-Resources Investigations Report 97-4280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

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**
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.

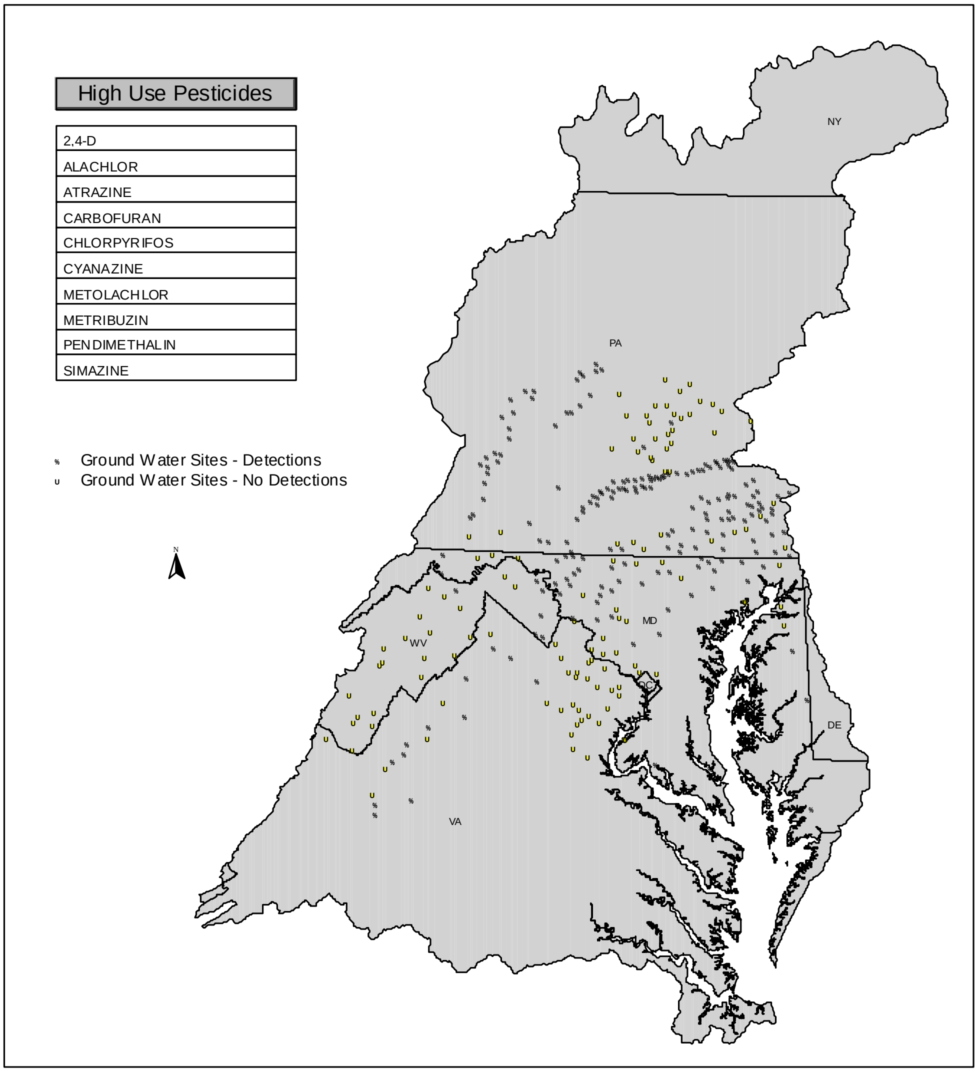
Note: These data are from USGS's Mid-Atlantic Assessment (MAIA) project: nitrogen and pesticide concentrations for 937 ground water sites. Only data from 1993-1996 within the Chesapeake Bay Watershed were used for this analysis.



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.

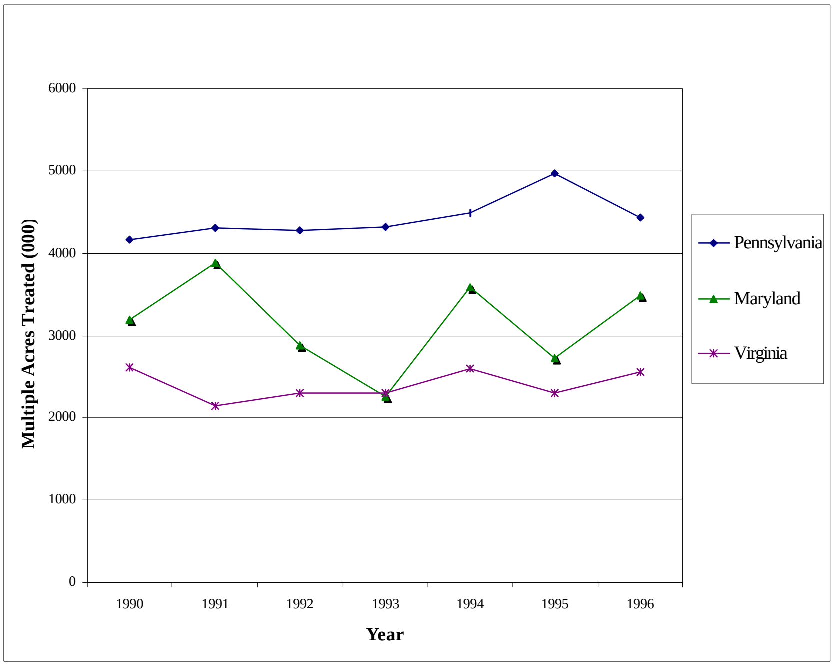


Figure 7.3. Multiple Acres Treated With Pesticides Within the Watershed.

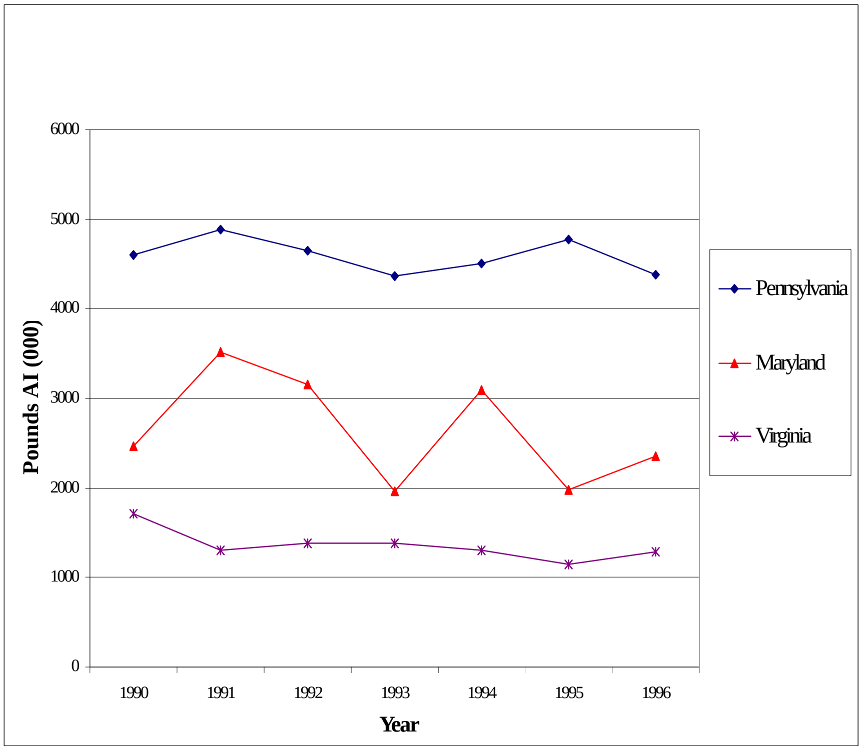


Figure 7.4. Pounds of Pesticide Active Ingredients Applied to Agricultural Lands Within the Watershed.

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 (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 (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.

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 ±10% and ±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 ± 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 µg/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 µg/L (sum of 71 target congeners) with an overall average of 0.025 µg/L. Concentrations of total PCBs from 7 WWTP in the tidal freshwater Delaware River (DRBC, 1998), ranged from approximately 0.0014 to 0.045 µg/L with an overall average of 0.013 µg/L.

Assuming a low and high concentration of 0.0014 µg/L and 0.05 µg/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 ± 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 ± 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 ±10% estimate of modeling error due to land use with the ±16% error from the interannual runoff variability, the uncertainty in the calculated runoff values is likely to be about ±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 ±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 ± 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 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.

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 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 complied 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^2-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^2-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.

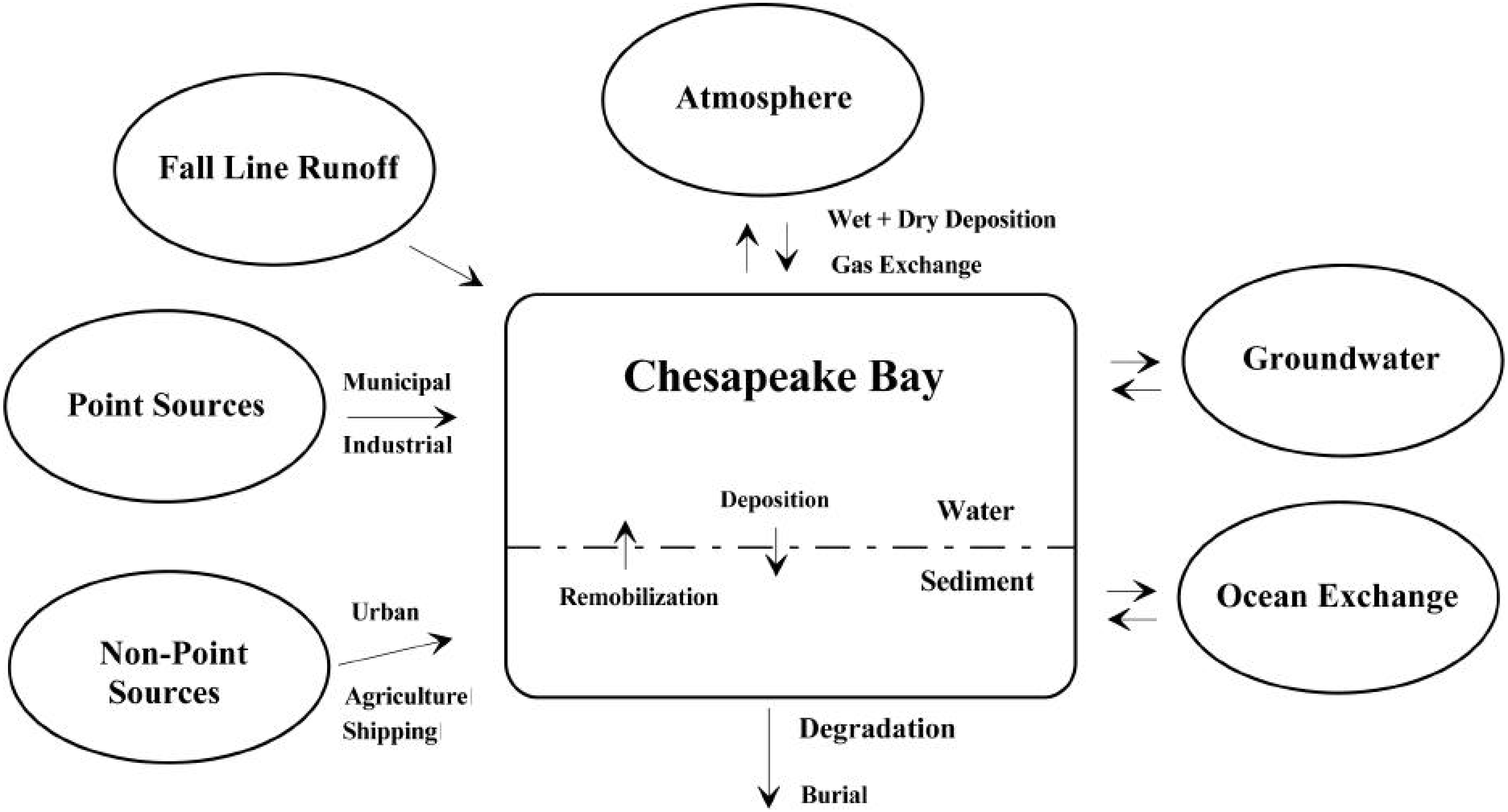
DISCUSSION AND RECOMMENDATIONS

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 <u>accurately</u> 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.


Atmosphere
Fall Line Runoff
Wet + Dry Deposition
Gas Exchange
Chesapeake Bay
Point Sources
Municipal
Industrial
Groundwater
Deposition
Water
Sediment
Remobilization
Ocean Exchange
Urban
Non-Point Sources
Agriculture
Shipping
Degradation
Burial

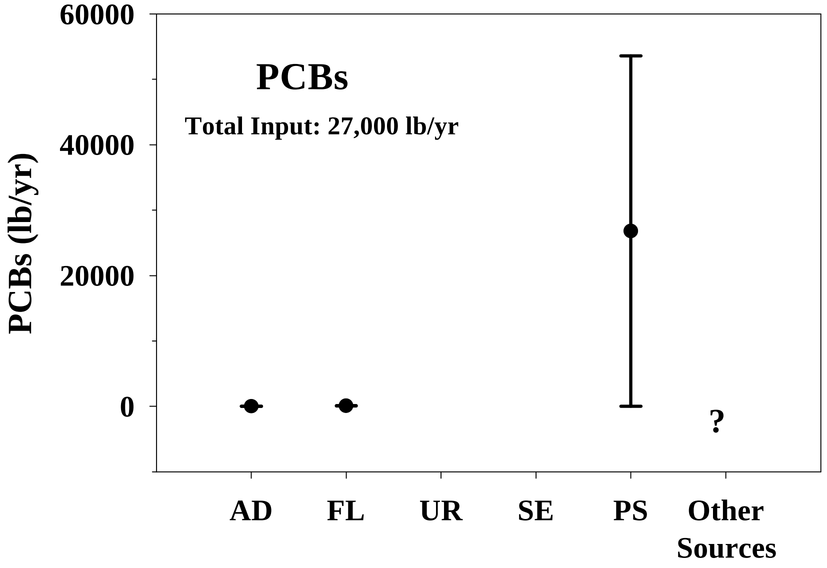


Figure 8.2. Total loads of PCBs to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

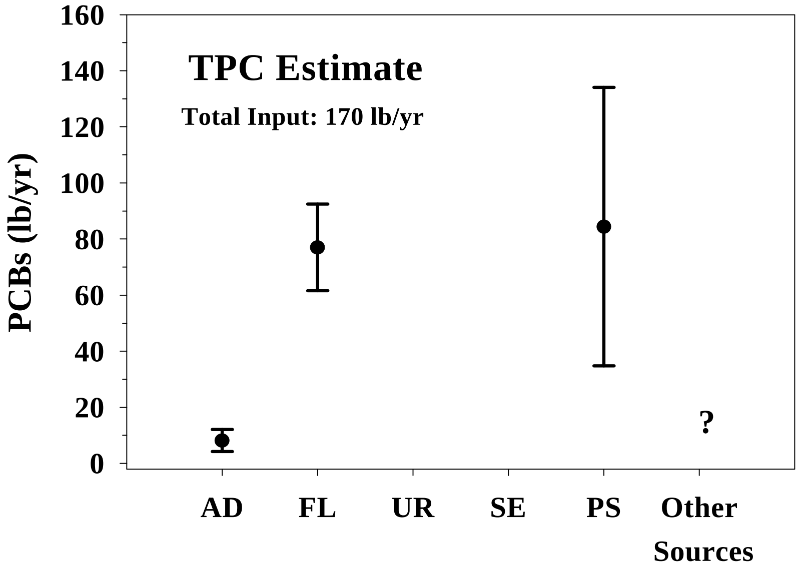


Figure 8.3. Total estimated loads of PCBs to the tidal Potomac River based on typical pollutant concentrations (TPC) from the literature from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified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

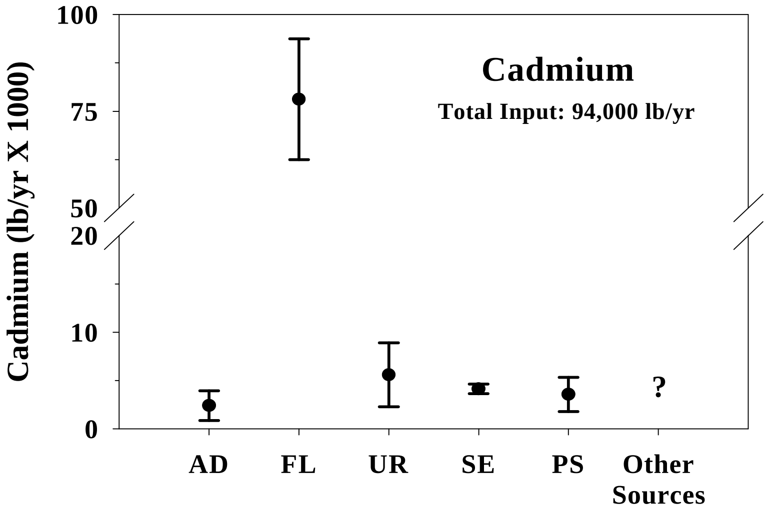


Figure 8.4. Total loads of cadmium to the tidal waters of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural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

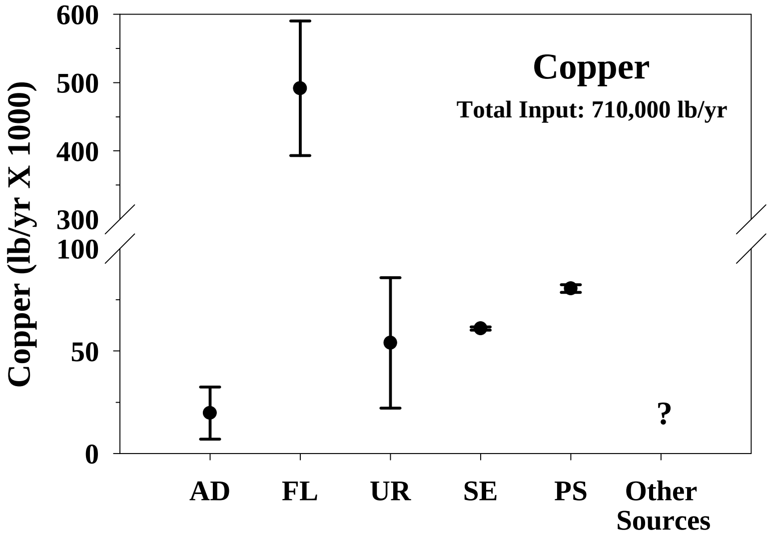


Figure 8.5. Total loads of copper to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural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

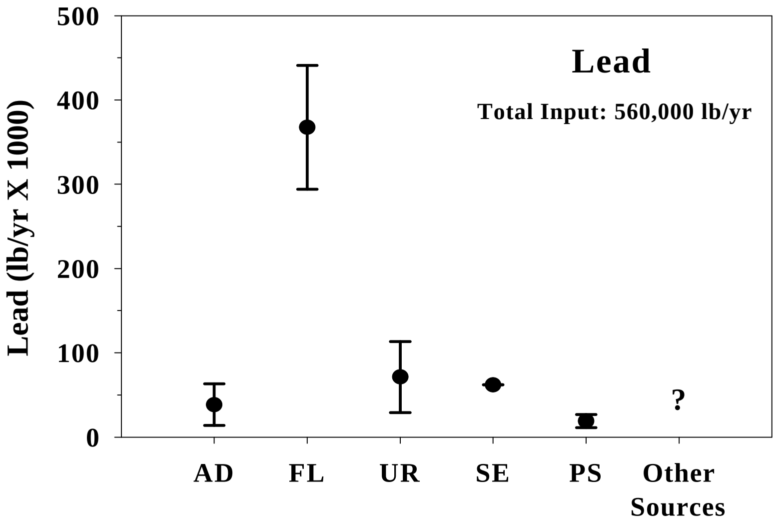


Figure 8.6. Total loads of lead to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff,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

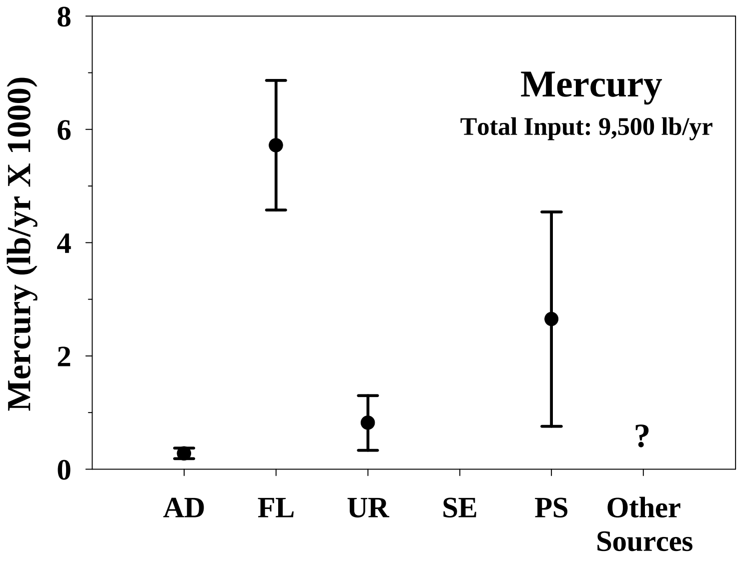


Figure 8.7. Total loads of mercury to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural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

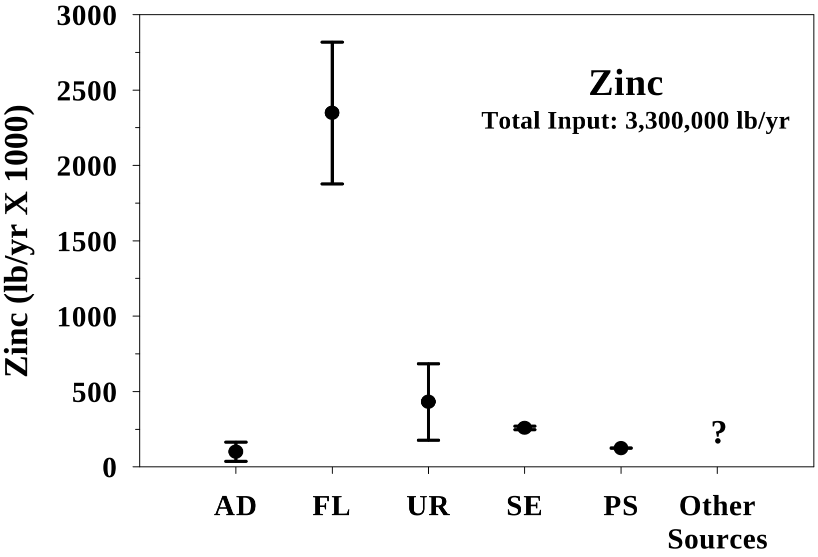


Figure 8.8. Total loads of zinc to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff,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

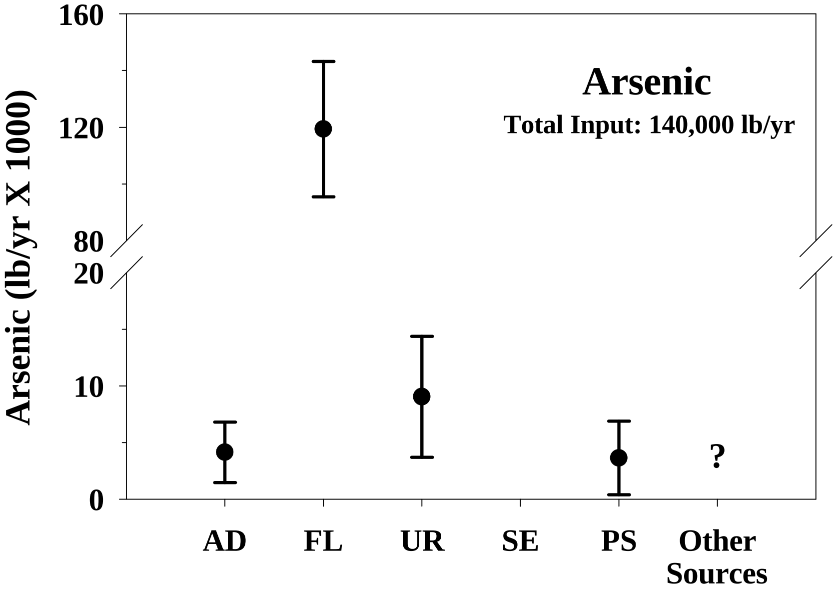


Figure 8.9. Total loads of arsenic to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural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

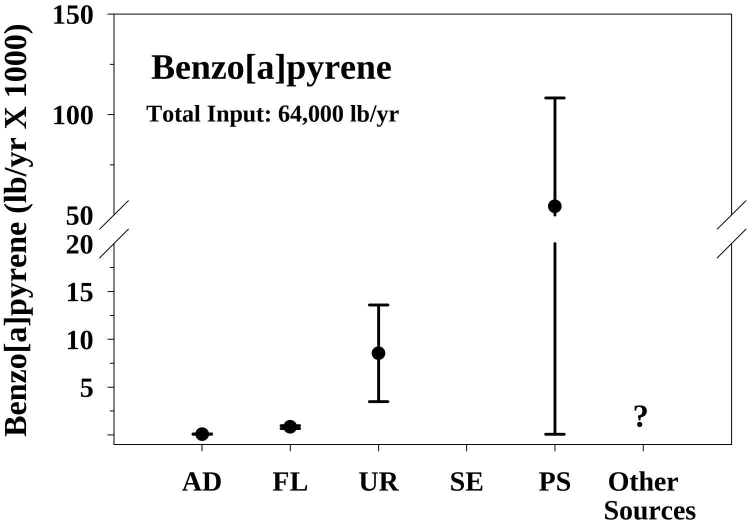


Figure 8.10. Total loads of benzo[a]pyrene to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural 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.

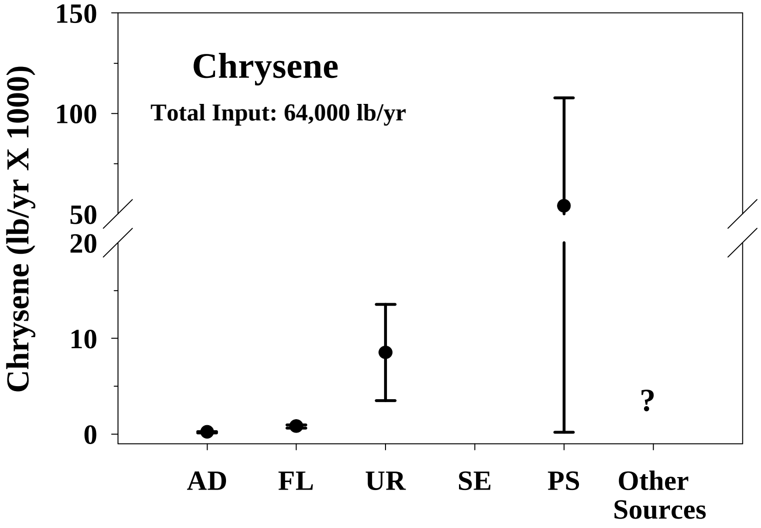


Figure 8.11. Total loads of chrysene to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural 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.

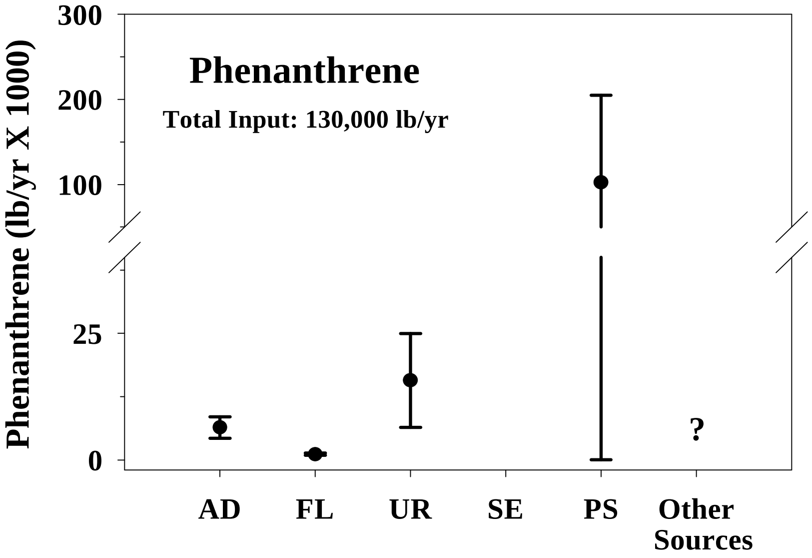


Figure 8.12. Total loads of phenanthrene to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural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

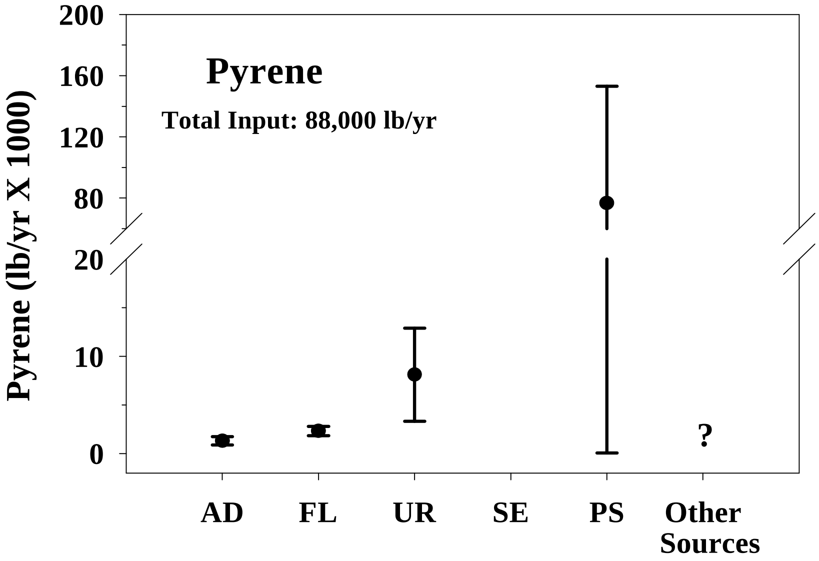


Figure 8.13. Total loads of pyrene to the tidal water of the Chesapeake Bay from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural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

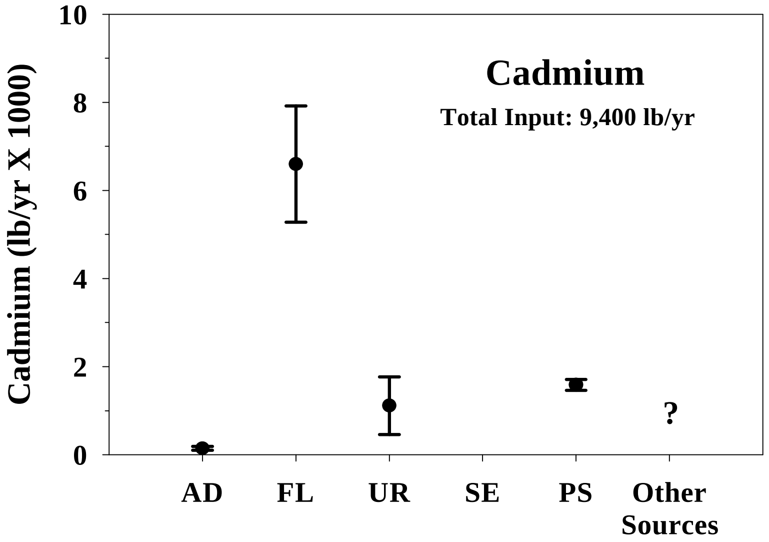


Figure 8.14. Total loads of cadmium to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

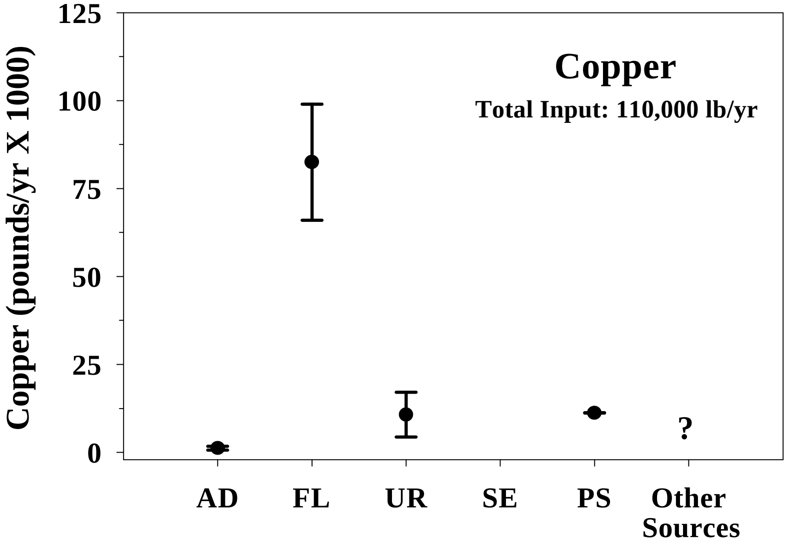


Figure 8.15. Total loads of copper to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

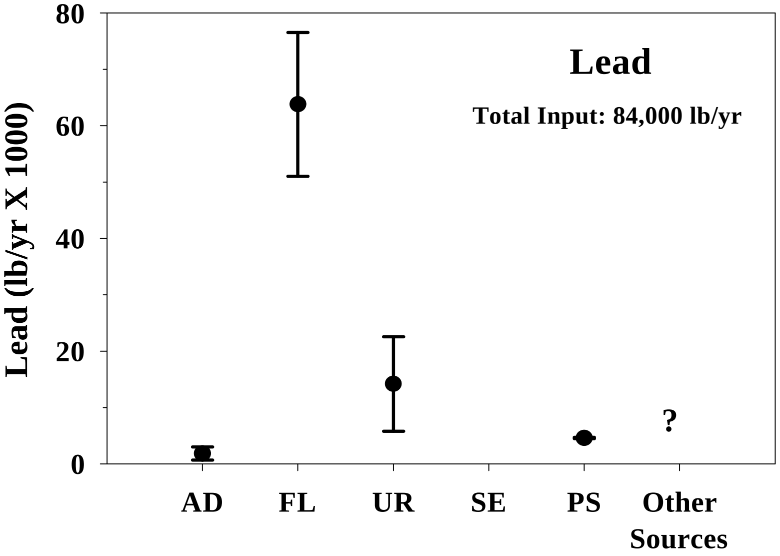


Figure 8.16. Total loads of lead to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

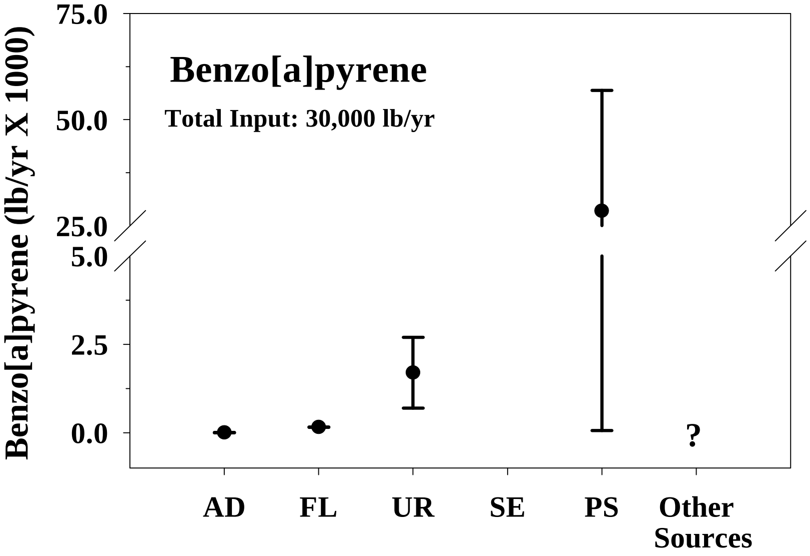


Figure 8.17. Total loads of benzo[a]pyrene to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff,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

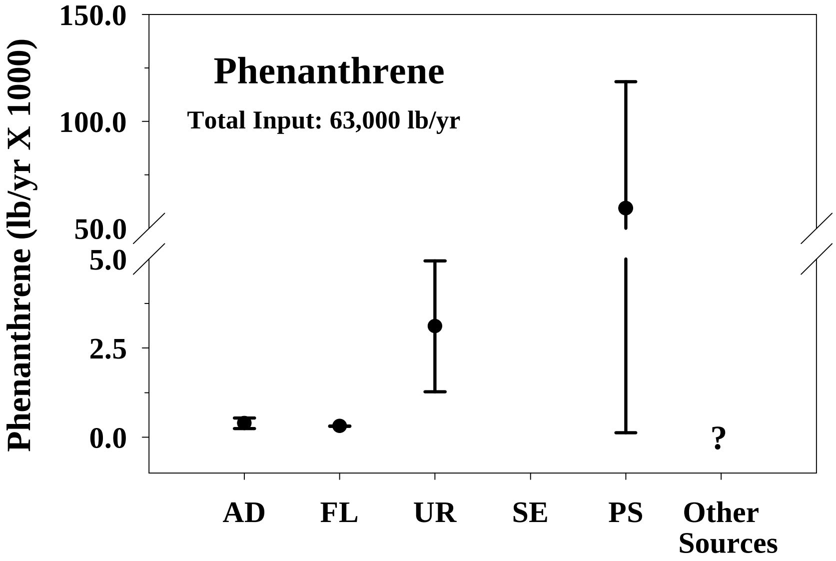


Figure 8.18. Total loads of phenanthrene to the tidal James River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

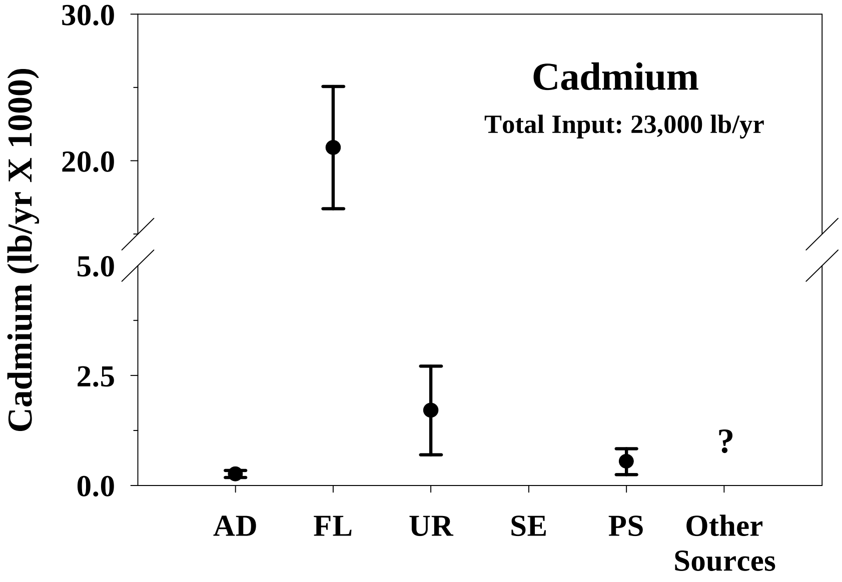


Figure 8.19. Total loads of cadmium to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

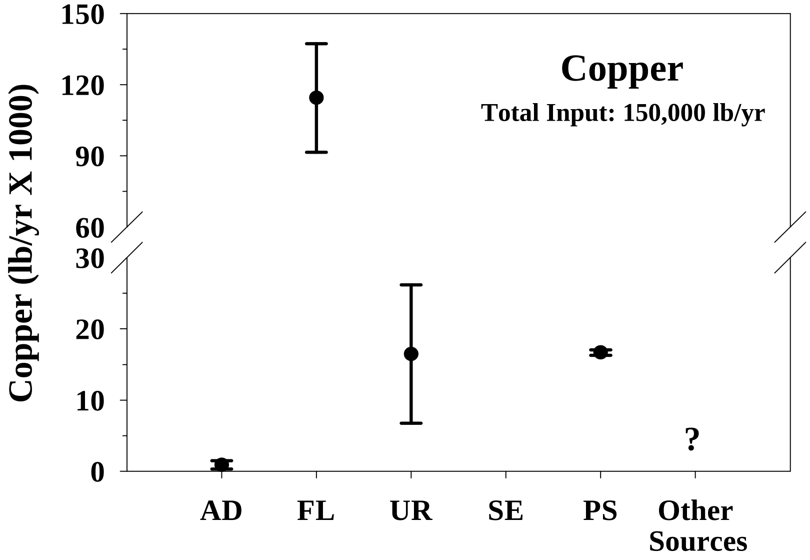


Figure 8.20. Total loads of copper to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

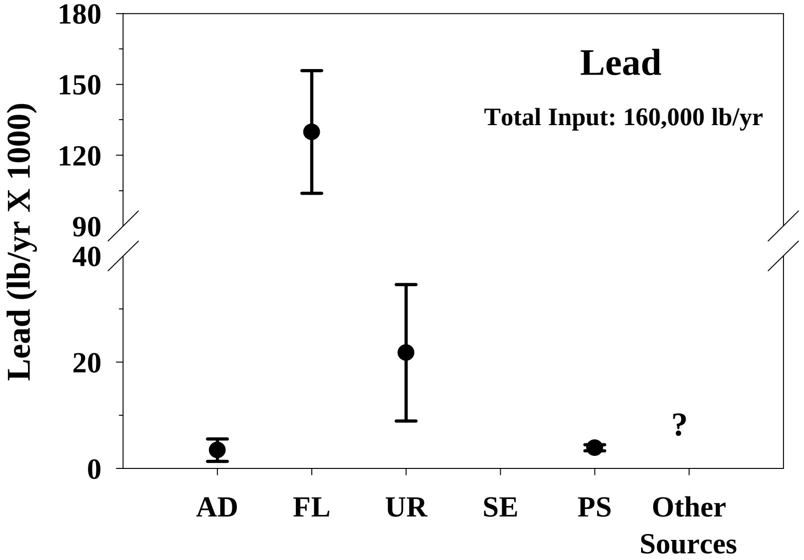


Figure 8.21. Total loads of lead to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

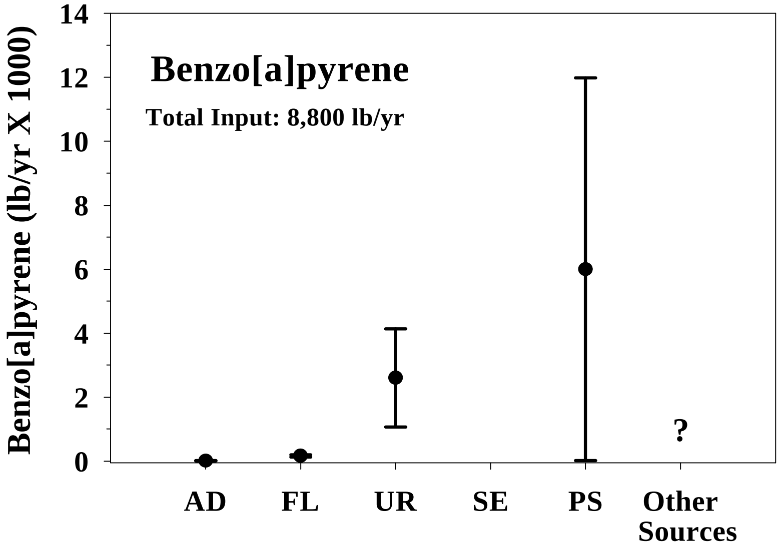


Figure 8.22. Total loads of benzo[a]pyrene to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff,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

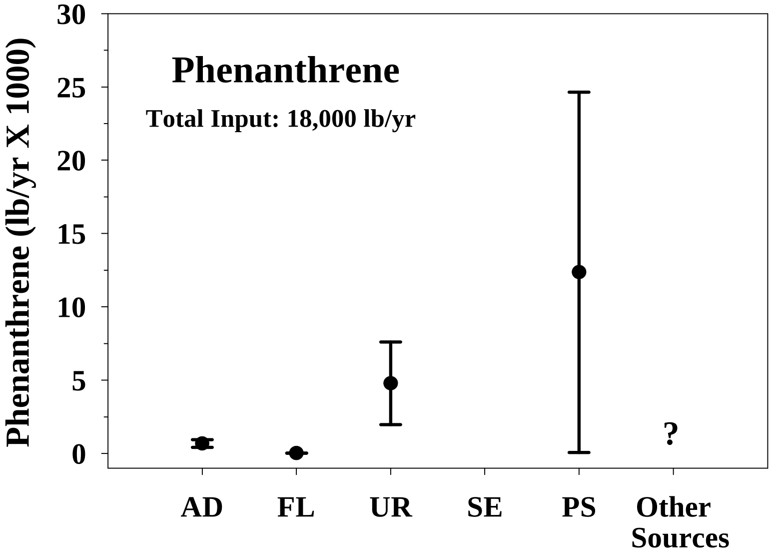


Figure 8.23. Total loads of phenanthrene to the tidal Potomac River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of “Other Sources” not fully quantified may include loads from smaller point sources, agricultural runoff,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

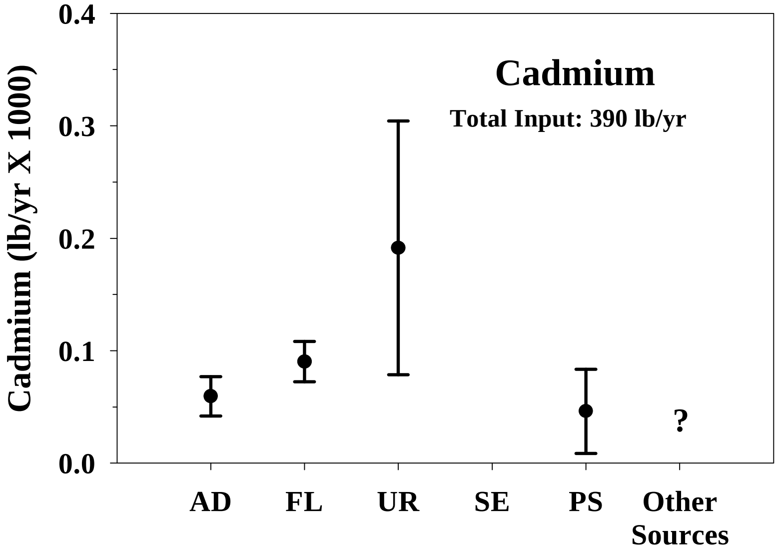


Figure 8.24. Total loads of cadmium to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

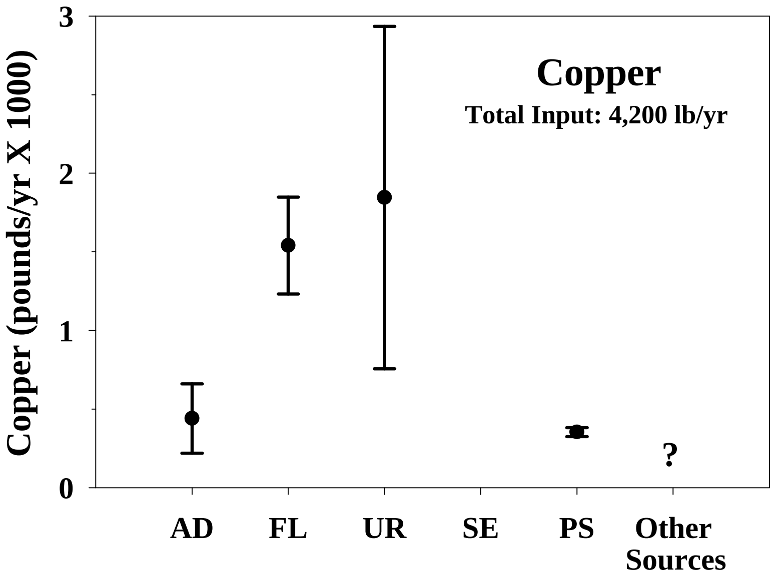


Figure 8.25. Total loads of copper to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

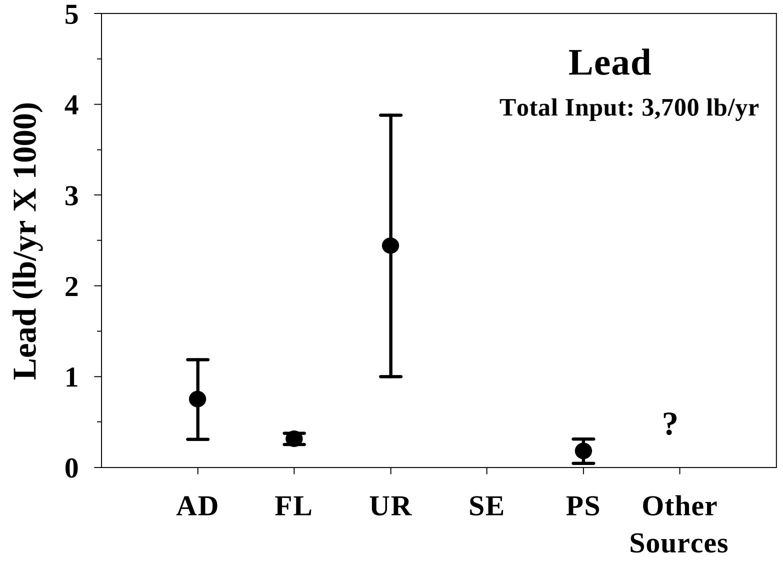


Figure 8.26. Total loads of lead to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff, atmospheric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

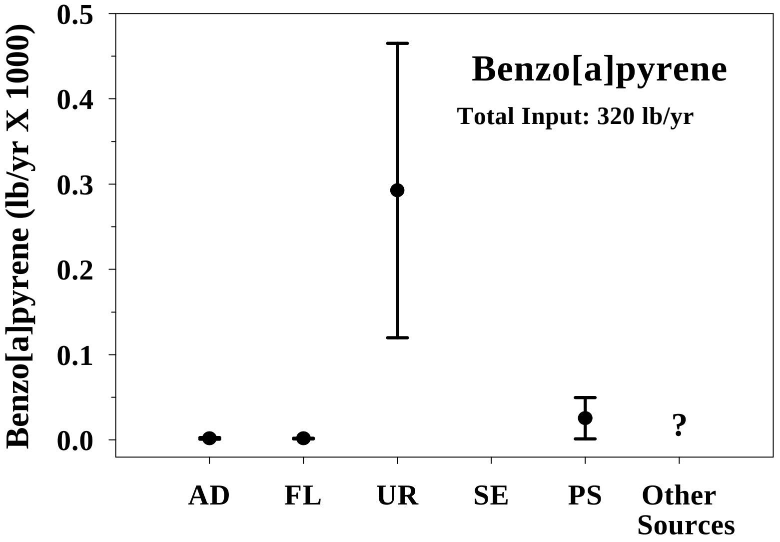


Figure 8.27. Total loads of benzo[a]pyrene to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff,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

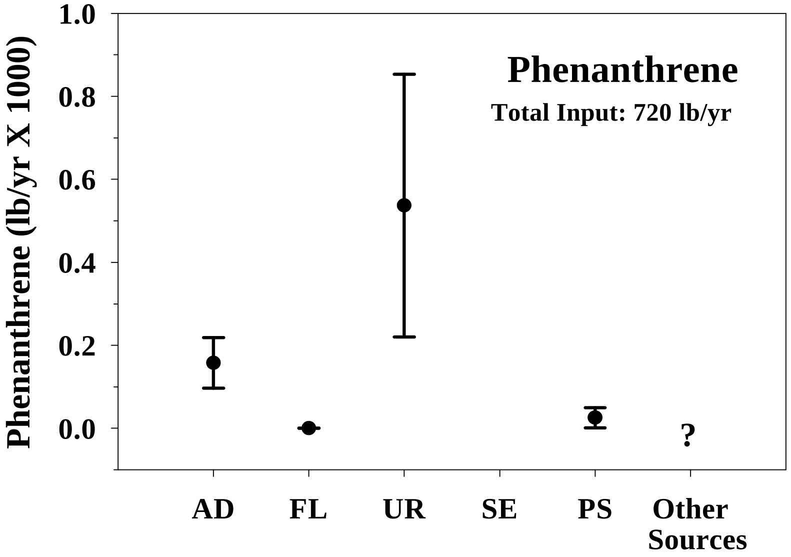


Figure 8.28. Total loads of phenanthrene to the tidal Patuxent River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); shoreline erosions (SE); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff,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

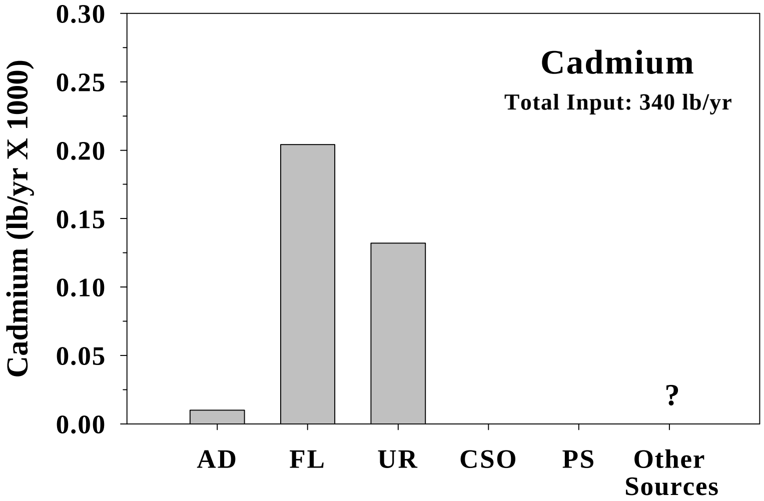


Figure 8.29. Total loads of cadmium to the tidal Anacostia River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); combined sewer overflow (CSO); and point sources (PS). Point source loadings were not reported. Examples of "Other Sources" not fully quantified may include loads from 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.

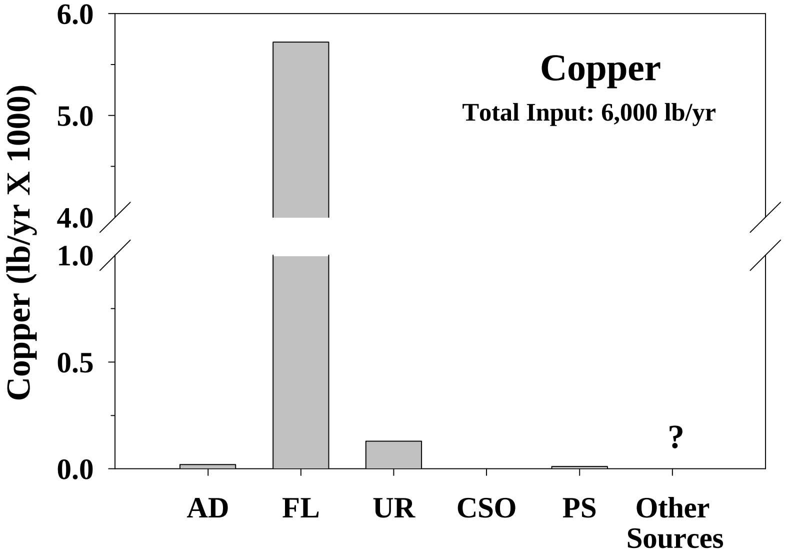


Figure 8.30. Total loads of copper to the tidal Anacostia River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); combined sewer overflow (CSO); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff,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

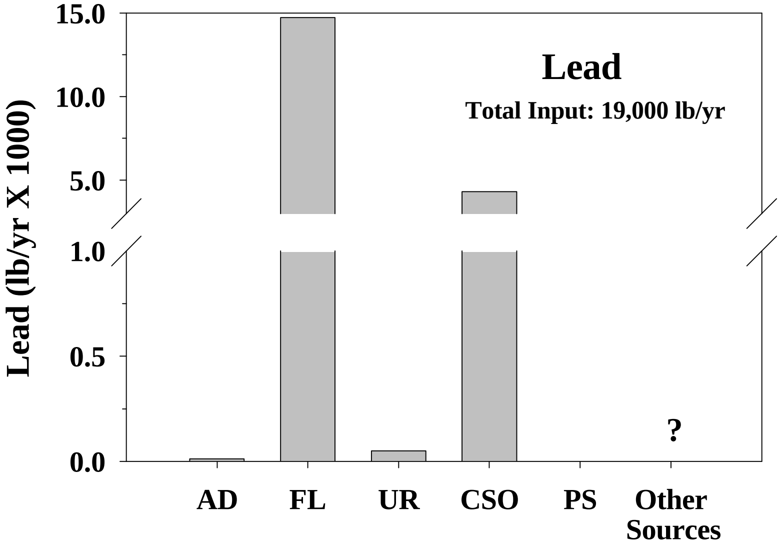


Figure 8.31. Total loads of lead to the tidal Anacostia River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); combined sewer overflow (CSO); and point sources (PS). Point source loadings were not reported. Examples of "Other Sources" not fully quantified may include loads from smaller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

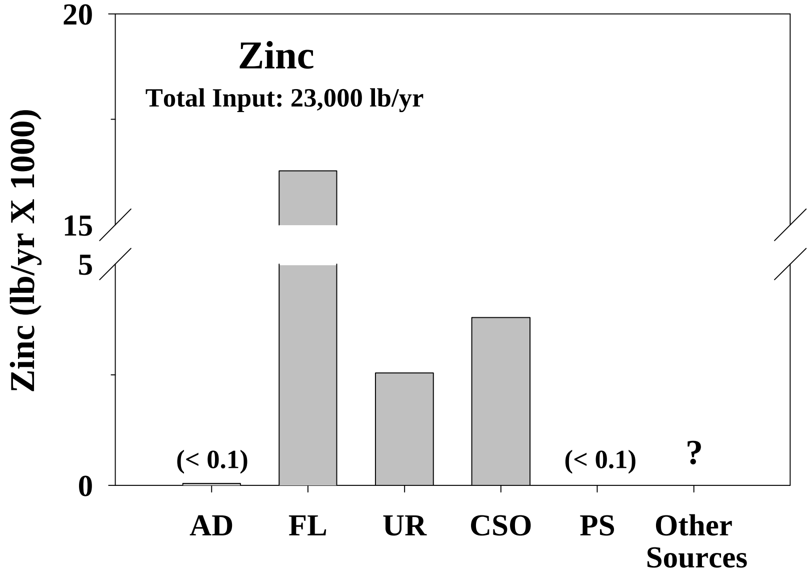


Figure 8.32. Total loads of zinc to the tidal Anacostia River from atmospheric deposition (AD); fall line (FL); urban runoff (UR); combined sewer overflow (CSO); and point sources (PS). Examples of "Other Sources" not fully quantified may include loads from smaller point sources, agricultural runoff,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

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 obtain 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 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 loadings 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.

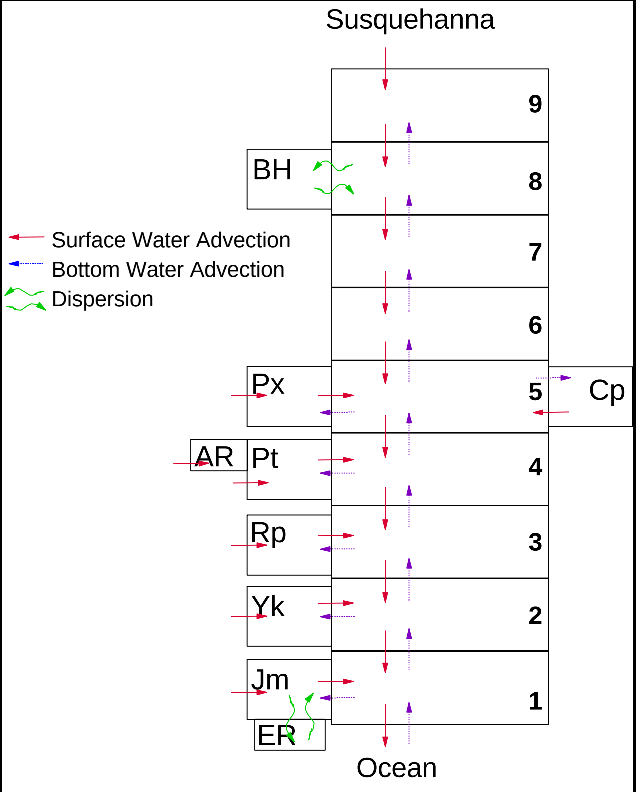

Figure 9.1. Schematic of Chesapeake Bay Chemical Contaminant Mass Balance Model (after Hagy, 1998).

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 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). Gross advective transport between adjacent cells is calculated as the product of the estimated concentration of the chemical in the cell (g/m^3) and the water transport flux (m^3/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 (g/m^3) is then multiplied by a ‘settling velocity’ term (equal to 1 m/day in this model) and the interfacial area (m^2) to estimate the settling flux (g/day). Long-term net rates of chemical burial in sediments is calculated as the product of the measured (or interpolated)

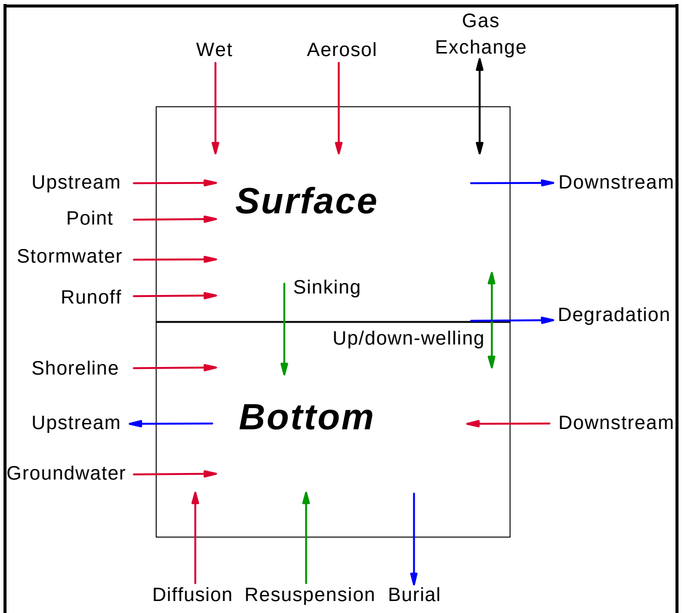

Figure 9.2. Flows of chemical contaminants into and from model cells.

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 <u>direct</u> 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 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 µg/m^2-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.

	Total Load Below Fall-Lines	**Total Load to Mainstem**	**Total Load to Tributaries (by difference)**
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
TOTAL	322,000	118,000	204,200

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
TOTAL MAINSTEM LOSSES	107,000

Units: kg/yr

Table 9.3. Loadings of Mercury to Chesapeake Bay.

	Total Load Below Fall-Lines	**Total Load to Mainstem**	**Total Load to Tributaries (by difference)**
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
TOTAL	4,540	420	4,120

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
TOTAL MAINSTEM LOSSES	1,760

Units: kg/yr

Table 9.5. Loadings of total PCBs to Chesapeake Bay.

	Total Load Below Fall-Lines	**Total Load to Mainstem**	**Total Load to Tributaries (by difference)**
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
TOTAL	410,400	183	410,300

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
TOTAL MAINSTEM LOSSES	1,180

Units: kg/yr

Table 9.7. Loadings of Phenanthrene to Chesapeake Bay.

	Total Load Below Fall-Lines	**Total Load to Mainstem**	**Total Load to Tributaries (by difference)**
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
TOTAL	57,510	4,360	53,300

Units: kg/yr.

Table 9.8. Losses of Phenanthrene from the Mainstem Chesapeake Bay.

Export to the Ocean	750
Degradation (k=0.045 day^{-1})	2,860
Burial in Sediments	700
TOTAL MAINSTEM LOSSES	4,310

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 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-METHYLNAPTHTHALENE	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[GHI]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

		# OF FACILITIES UNDER SIC		PAHs		PCBs		PESTICIDES	
SIC CODE	SIC CODE DESCRIPTION	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.