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CHEMICAL-QUALITY RECONNAISSANCE OF THE WATER AND SURFICIAL BED MATERIAL IN THE DELAWARE RIVER ESTUARY AND ADJACENT NEW JERSEY TRIBUTARIES, 1980-81

By Joseph J. Hochreiter, Jr.

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 82-36

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NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION,

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June 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

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GLOSSARY OF TERMS

Appalachian Highlands. A major physiographic subdivision of the United States that, in New Jersey, includes parts of the following physiographic provinces: (1) Piedmont, (2) New England, (3) Valley and Ridge, and (4) Appalachian Plateaus. Each province is characterized by distinctive landforms related to the structure and types of rocks contained therein and to the geologic history of the province.

DDT-T. A term used in this report to collectively identify DDT (dichlorodiphenyltrichloroethane) and its metabolites, DDD (dichlorodiphenyldichloroethane) and DDE (dichlorodiphenyldichloroethylene).

Delaware Estuary. The entire tidal segment of the Delaware River including the Bay, from river mile 0.0 at the entrance of Delaware Bay to river mile 133 at the head of tide at Trenton, N.J.

Delaware River estuary. That segment of the Delaware Estuary, not including the bay, from river mile 48.23 at the mouth of the Delaware River to river mile 133 at the head of tide at Trenton, N.J.

Delaware Valley. For the purposes of this report, a region as defined by the Delaware Valley Regional Planning Commission that covers a total of 3,840 square miles in the center of the eastern seaboard. This area includes Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties in Pennsylvania; Burlington, Camden, Gloucester, and Mercer Counties in New Jersey.

Dissolved. That material in a representative water sample which passes through a 0.45-micrometer membrane filter. This is a convenient operational definition used by Federal agencies that collect water data. Determinations of "dissolved" constituents are made on subsamples of the filtrate.

EPA priority pollutants. A list of 129 materials developed by the U.S. Environmental Protection Agency (Keith and Telliard, 1979) in implementing parts of the Federal Water Pollution Control Act (Public Law 92-500) which deals with toxic pollutants in water. These materials include purgeable, acid extractable, and base/neutral extractable organic compounds, pesticides, metals, cyanides, asbestos, and polychlorinated biphenyls (PCB's).

Fall Line. A line characterized by the outcrop of bedrock that divides the rolling topography of the Piedmont physiographic province from the relatively flat plains of the Coastal Plain physiographic province. The line runs parallel and just to the northwest of the Delaware River estuary from below Wilmington, Del., through Trenton, N.J. The point at which the Fall Line crosses the Delaware River is considered to be the head of tide.

Micrograms per liter (µg/L). A unit expressing the concentration of a chemical constituent in solution as the mass (1 microgram = 1×10^{-6} gram) of solute per unit volume (liter) of water. One µg/L is approximately equal to 1 part per billion (PPB) in aqueous solutions of low dissolved-solids concentration.

Micrograms per gram (µg/g) or kilogram (µg/kg). A unit expressing the concentration of a chemical constituent as the mass (microgram) of the substance sorbed per unit mass (gram/kilogram) of sediment.

Milligrams per liter (mg/L). A unit expressing the concentration of chemical constituents in solution as the mass (1 milligram = 1×10^{-3} gram) of solute per unit volume (liter) of water. One mg/L is approximately equal to 1 part per million (PPM) in aqueous solutions of low dissolved-solids concentration.

Minimum detection limit. For a given type of sample and analytical procedure, it is that concentration value below which the presence of the constituent being analyzed cannot be verified or denied. Minimum detection limits can be identified in tables 6 and 8 of this report by a zero (0) or by a less than (<) symbol preceding a numerical value.

Organic compounds, acid extractable (EPA priority pollutants). A group of 11 semivolatile phenolic compounds. These compounds are extracted with methylene chloride from a water sample under acidic conditions prior to analysis by gas chromatography-mass spectrometry (GC-MS).

Organic compounds, base-neutral extractable (EPA priority pollutants). A group consisting of 46 semivolatile compounds from various chemical families extracted with methylene chloride from a water sample under alkaline conditions prior to analysis by GC-MS.

Organic compounds, purgeable (EPA priority pollutants). A group of 31 organic compounds which, because of their volatile nature, can be stripped as a vapor from a water sample via the injection of an inert gas prior to analysis by GC-MS. Two compounds (acrolein, acrylonitrile) of this group actually remain part of the water sample after vapor stripping. These compounds are analyzed by direct aqueous injection GC-MS. As a group, these compounds are of lower molecular weight than acid or base/neutral extractable compounds, and often have higher vapor pressures. Their boiling points are less than 150°C.

River mile. A system of computing center channel stream length. The values used in this report were adopted from the table of river miles used by the Delaware River Basin Commission.

Sampling vertical. A sampling location that represents the depth of a stream at a single point along the horizontal cross section of a stream or estuary.

Sediment. A solid material that originates mostly from disintegrated rocks and is transformed by, suspended in, or deposited from water; it includes chemical and biochemical precipitates and decomposed organic material such as humus. The quantity, characteristics, and cause of the occurrence of sediment in streams are influenced by degree of slope, length of slope, soil characteristics, land use, and quantity and intensity of precipitation.

Specific conductance. A measure of the ability of a water to conduct an electrical current expressed in micromhos per centimeter at 25°C. Because the specific conductance is related to the number and specific chemical types of ions in solution, it may be used for approximating the dissolved solids content in the water. Commonly, the amount of dissolved solids (in milligrams per liter) is about 65 percent of the specific conductance (in micromhos per centimeter at 25°C). This relation is not constant from stream to stream or from well to well, and it may even vary in the same source with changes in the composition of the water.

Surficial bed material. The upper segment (0.1 to 0.2 ft) of unconsolidated material which is deposited on the bottom of a streambed, lake, pond, reservoir, or estuary. Only material which passes through a 2-millimeter sieve is accepted for the chemical analyses described in this text.

Suspended sediment. The sediment that at any given time is maintained in suspension by the upward components of turbulent currents or that exists in suspension as a colloid in a water column.

CONVERSION OF INCH-POUND UNIT TO INTERNATIONAL SYSTEM (SI) UNITS

The following factors may be used to convert the inch-pound units published herein to the International System of Units (SI).

Multiply Inch-Pound Unit	By	To Obtain SI Unit
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	30.48	centimeter (cm)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Specific Conductance	
micromho per centimeter at 25°C (µmho/cm at 25°C)	1.000	microsiemens per centimeter at 25°C (µS/cm at 25°C)
	Mass	
ton (short, 2,000 lb)	.9072	ton (metric)

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INTRODUCTION

In recent water-quality studies of surface-water systems, chemical analyses of bed material deposits in stream channels have been used as indicators of past contamination. Some contaminants, especially organic substances, evade detection in water due to their typically low concentrations, erratic distribution patterns, and generally low solubilities. The chemical quality of any river is dependent not only on the quality of the water and aquatic life within the river, but also on the chemical composition of the channel deposits and the interactions that might exist between these deposits and the water. Many constituents are sorbed onto suspended sediment particles that are later deposited onto the streambed (Feltz, 1980). Over time, these contaminants accumulate in the bed material at concentrations many times greater than originally present in the water.

An investigation by Sheldon and Hites (1978) detected nearly 100 organic compounds in the water of the Delaware River estuary between Trenton, N.J., and Marcus Hook, Pa., noting a predominance of ethylene glycol derivatives. Data collected by the U.S. Geological Survey throughout the 1970's indicate that some of the bed material along the Delaware River main stem contains organochlorine insecticides and PCB's. Additional data collected by the U.S. Geological Survey in 1979 suggest that substantial quantities of trace metals and organic compounds, including polychlorinated biphenyls (PCB's) have been deposited in the sediments of the Delaware River estuary (U.S. Geological Survey, 1980).

Much of the Delaware River estuary overlies the outcrop of the Potomac-Raritan-Magothy aquifer system. Existing potentiometric heads indicate that recharge from the river to this aquifer system occurs through sections of estuarine bed material. This condition might induce the transport of contaminants from the surface water and bed material to the aquifer system.

Purpose and Scope

The U.S. Geological Survey, in cooperation with the New Jersey Department of Environmental Protection, Division of Water Resources, is investigating the chemical quality of ground water and surface water in the vicinity of the Potomac-Raritan-Magothy aquifer system outcrop from Trenton to Pennsville, N.J. The study began in October 1979 and will continue through September 1983.

This report discusses the occurrence and distribution of selected chemical-quality constituents, including U.S. Environmental Protection Agency (EPA) "priority pollutants" (Keith and Telliard, 1979), in surface water and associated surficial bed materials of the Delaware River estuary and selected New Jersey tributaries. Thirteen surface-water and 10 bed material sites were sampled between Trenton and Pennsville from May 20, 1980, through January 8, 1981. Emphasis in this report is placed on the investigation of trace metals and organic compounds in the surficial bed material.

Acknowledgments

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THE DELAWARE RIVER ESTUARY

Location and Extent

The Delaware Estuary basin drains approximately 5,900 mi^2, excluding the surface area of the bay, and represents the tidal part of the Delaware River and Delaware Bay. The Delaware River estuary extends from the head of tide at Trenton, N.J., south to river mile 48.23 at the head of the bay (fig. 1). The entire Delaware River basin drains 12,765 mi^2 (excluding the surface area of the bay) from parts of New York, Pennsylvania, New Jersey, Maryland and Delaware (Parker and others, 1964). The estuary begins in Trenton, N.J. at the Fall Line, which separates the Appalachian Highlands from the Atlantic Coastal Plain. The large industrial cities of Philadelphia, Pa. (1980 population, 1,688,210), Camden, N.J. (84,910), Chester, Pa. (45,794), and Wilmington, Del. (70,195) are located along the Delaware River estuary. The 1980 population of the nine-county Delaware Valley region is over 5 million (David Lewis, U.S. Census Bureau, oral communication, 1981). The Delaware River estuary supplies water for domestic use to several communities, including Philadelphia. The estuary serves one of the largest freshwater ports in the country, and a shipping channel is dredged and maintained from Bordentown, N.J., south to the bay.

Climate

The Delaware Estuary basin has a moderate, primarily continental climate. The mean annual temperature at Trenton is 54°F (12.2°C) with a range in mean monthly temperature from 32°F (0°C) in January to 76°F (24.4°C) in July. Average annual precipitation during 1941-70 at Trenton was 40.17 inches. October and February are the driest months, with mean monthly precipitation of 2.5 in. and 2.7 in., respectively. The wettest months typically are July and August, with mean monthly precipitation of 4.7 in. and 4.1 in., respectively (U.S. National Oceanic and Atmospheric Administration, 1973).

Total precipitation during the sampling period from May to December 1980 was 3.75 in. below a mean of 27.52 in. at Philadelphia and 7.07 in. below a mean of 28.68 in. in the basin above Trenton (Delaware River Basin Commission, written communication, 1981). The annual precipitation at Trenton for 1980 was 34.17 in. (U.S. National Oceanic and Atmospheric Administration, oral communication, 1981).

Geography and Geology

The Delaware River estuary lies almost entirely in the northern Atlantic Coastal Plain. All drainage into the Delaware River basin north of Trenton, as well as most of the drainage into the estuary from Pennsylvania, originates in the Appalachian Highlands. Drainage into the estuary from New Jersey and most of Delaware originates in the Atlantic Coastal Plain. The geologic characteristics of both the Coastal Plain and Appalachian Highlands provinces contribute to the deposition of sediment within the estuary.

Mansue and Commings (1974, p. H17) report that, on the average, 1.6 million tons of sediment is transported into the Delaware estuary annually. Of this amount, the Delaware River main stem transports 48 percent, streams draining the Piedmont

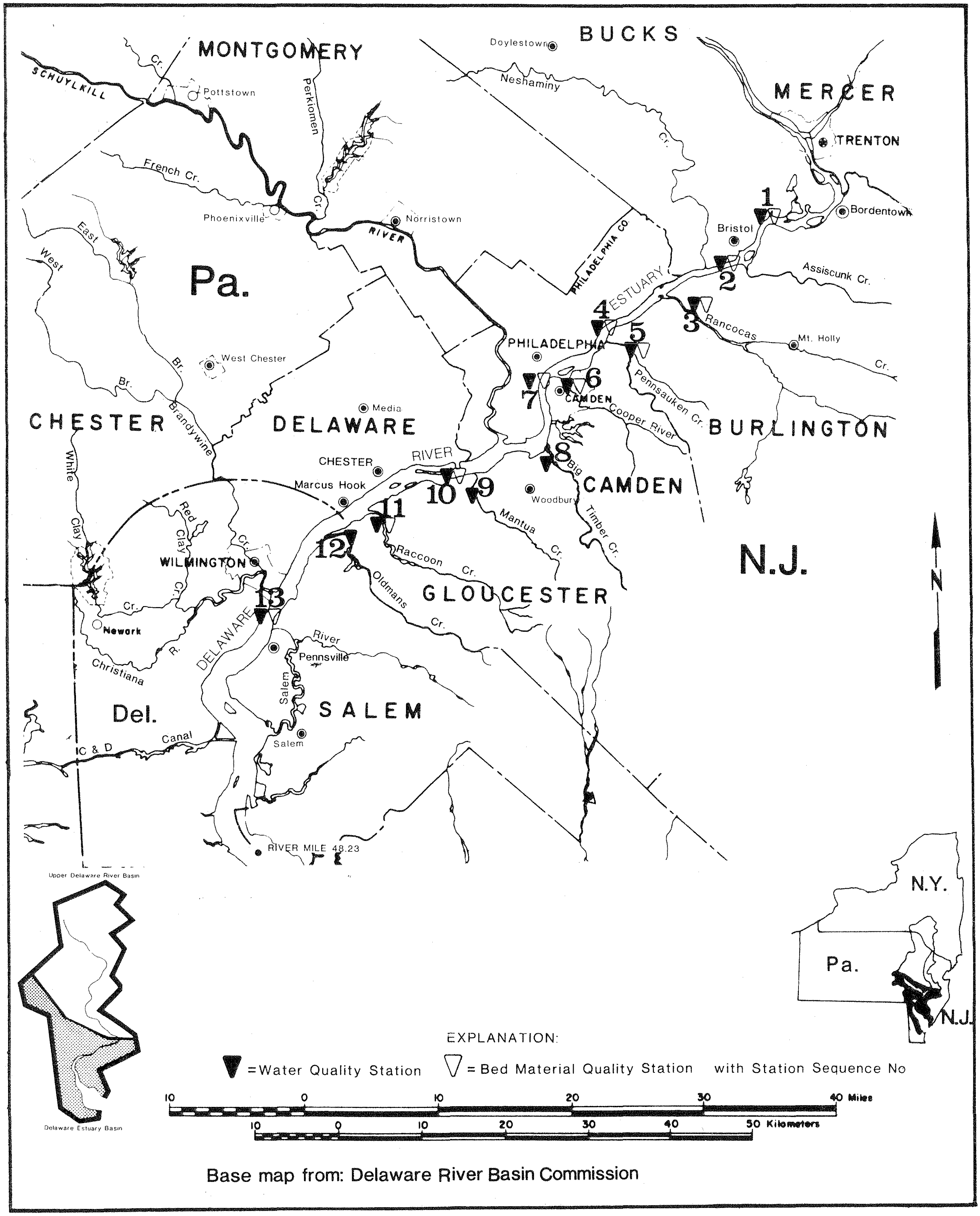


Figure 1.— Map of the Delaware River estuary showing the location of sampling sites.

Physiographic province transport 42 percent, and streams draining the Atlantic Coastal Plain transport about 10 percent. Of the remaining 52 percent of annual sediment transported from sources other than the main stem, Pennsylvania tributaries contribute 34 percent, and New Jersey and Delaware tributaries each contribute 9 percent (Mansue and Commings, 1974, p. H17). Weil (1977, p. 15) reports that approximately 65 percent of all sediment transported into the estuary is deposited in the dredged navigation channel and anchorage areas between the head of Delaware Bay and Philadelphia.

The geology of the Coastal Plain in New Jersey is characterized by a wedge of unconsolidated sediments that thickens and dips toward the Atlantic Ocean. The Potomac Group and Raritan and Magothy Formations of Cretaceous age are the oldest of these sediments. These deposits overlie Precambrian and Paleozoic crystalline rock and crop out along the Fall Line bordering the Appalachian Highlands in New Jersey and Pennsylvania.

The Potomac Group and Raritan and Magothy Formations are composed of interbedded sand and gravel, silt, and clay units. In parts of the outcrop area, the Cretaceous formations are overlain by more recent sediments, including the Pensauken Formation of late Miocene age, the Bridgeton Formation of Miocene age, and the Spring Lake and Van Sciver Lake beds of the late Pleistocene age (Owens and Minard, 1979).

Northwest of the Fall Line, the bedrock consists mainly of metamorphic and sedimentary rocks of Cambrian or possibly Precambrian age. Triassic rocks can be found at the surface in parts of Bucks and Montgomery Counties (Willard, 1962).

Ground-water Hydrology

The flow patterns within the Potomac-Raritan-Magothy aquifer system prior to ground-water development were controlled by the natural hydraulic gradients, reflecting the difference in elevation and the distance between recharge and discharge areas, as well as the geology and physical properties of the aquifers and confining units (Barksdale and others, 1958). The regional ground-water flow before development was controlled by recharge to two areas of the outcrop at high elevations (Barksdale and others, 1958) and by leakage from the Englishtown Formation, through the underlying confining unit in the Merchantville Formation and Woodbury Clay (Gill and Farlekas, written communication, 1969). As the water resources of the area were largely undeveloped, the aquifer discharged at many places into the Delaware River estuary, tributaries overlying the outcrop, and streams draining the Coastal Plain in southern New Jersey.

In 1978, about 230 Mgal/d was withdrawn from the Potomac-Raritan-Magothy aquifer system, accounting for approximately 70 percent of the total pumpage from the Coastal Plain in New Jersey (Vowinkel and Foster, 1981, p. 28). The extensive development of the aquifer system in the Camden County area has resulted in a decrease in potentiometric heads, reversing the original flow pattern so that recharge to the aquifer system is now induced from the Delaware River estuary in this area (Greenman and others, 1961, and Barksdale and others, 1958).

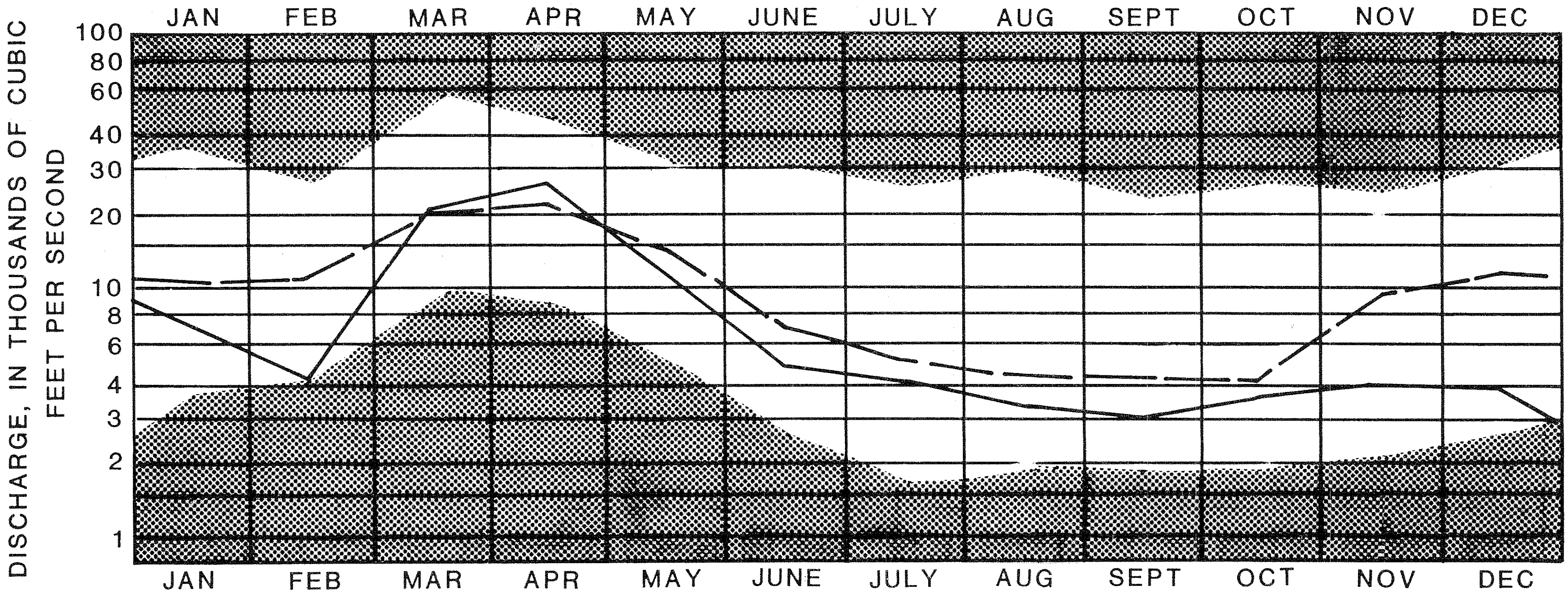
Although it is generally accepted that the estuary recharges the aquifer system, the specific distribution is largely unknown. Powell and others (1954) conducted aquifer tests and analyzed cores from the Delaware River estuary bed above Philadelphia and found many areas, particularly along the dredged channel, where water can easily flow through highly permeable bottom sediments. Barksdale and others (1958, p. 114-116) indicate that direct recharge from the estuary to the lower aquifer in the system would be unlikely in the Philadelphia-Camden area because of a clay layer. Luzier (1980, p. 21) suggests that direct recharge to the lower aquifer would be unlikely near the Delaware Memorial Bridge for similar reasons.

Luzier (1980) developed a two-dimensional digital simulation model of the Potomac-Raritan-Magothy aquifer system. The principal study area bordered both sides of the Delaware River estuary from Trenton to Wilmington. A simulation analysis for 1973 indicated that about 45 percent of the water withdrawn from this study area was induced recharge from the Delaware River estuary.

Surface-water Hydrology

The entire Delaware River estuary and the lower reaches of all its tributaries are affected by diurnal tidal fluctuations. According to Miller (1962, p. C22), during a typical tidal cycle, upstream flow rates are of higher intensity, yet net downstream flow is often of longer duration (Cohen and McCarthy, 1962, p. B10). The result is a net downstream discharge, in most cases, during a complete tidal cycle. Harleman and Lee (1969) report that, on the average at Philadelphia, a unit of water will travel 15 mi during a complete tidal cycle--7 mi upstream during high tide and 8 mi downstream during low tide. The mass transit time of water from Trenton to Marcus Hook is 43 days when the flow is 4,000 ft^3/s at Trenton (Keighton, 1966). Tidal reaches of the tributaries to the estuary experience similar fluctuations. The intensity of these fluctuations determines the amount of backwater that can enter the tributaries from the estuary during the incoming tidal cycle.

A decrease in freshwater inflow to the estuary and tributaries can diminish the ability of these bodies to flush out saline water and anthropogenic contaminants. The mean monthly streamflow for the calendar year 1980 is plotted in figure 2 against the median of the monthly means for the standard reference period at the Delaware River at Trenton. Table 1 shows that the flow in the Delaware River at Trenton for each month of the sampling period, May-December 1980, was substantially below the



Unshaded area.--Indicates range between highest and lowest mean recorded for the period, 1913-80

Dashed line.--Indicates the median of the monthly means for the standard reference period, 1941-70

Solid line.--Indicates observed monthly mean flow for the 1980 calendar year

Figure 2.-- Monthly streamflow for the Delaware River at Trenton, N.J.

median of record (1913-80) for that month. During November and December, the mean monthly flows were substantially less than the twenty-fifth percentile of flow, so that the mean discharge for May-December 1980 was 46 percent below the median of record for that period (1913-79) and 28 percent below the twenty-fifth percentile of flow.

Table 1.--Comparison of mean monthly discharge with median and normal discharge at the Delaware River at Trenton, N.J.

[In cubic feet per second]

Month (1980)	Monthly mean discharge for 1980	Median discharge for period of record (1913-80)	Twenty-fifth percentile of discharge for period of record (1913-80)	Percentage below the median	Percentage below the 25th percentile
May	11,920	12,650	10,060	5.7	-
June	4,874	7,176	5,085	32	-
July	4,008	5,222	3,726	23	-
August	3,198	4,547	2,991	30	-
September	2,981	4,231	2,780	30	-
October	3,512	5,061	3,176	31	-
November	3,985	9,825	4,725	59	16
December	3,784	10,860	7,358	65	49
Period:					
May-December	4,783	*8,830	*6,599	46	28

* Period of record (1913-79).

Land Use

Table 2 shows 1970 land use summaries for the nine-county area known as the Delaware Valley (Delaware Valley Regional Planning Commission, written communication, 1970). These values represent total county areas, including areas outside of the Delaware Estuary basin. Analyses of land use in these counties may help to determine the source of contaminants in the estuary.

The Delaware River Basin Commission (1975) inventoried over 100 industrial waste-water discharges along the Delaware Estuary and adjacent tidal tributaries. More manufacturing is done in Philadelphia and Delaware Counties in Pennsylvania than in any other Delaware Valley County. Camden and Gloucester counties are the most heavily industrialized New Jersey counties bordering the

Table 2.--Land use by county for the Delaware Valley (1970), in percent.

Source: Delaware Valley Regional Planning Commission, written communication, 1970

Counties	Area (mi²)	Land-use categories						Total land use*
		Residential	Utilities and transportation	Trade and services	Manufacturing	Resource production (principally agriculture)	Undeveloped and recreation	
Bucks	625	12.3	3.7	3.0	1.4	29.9	49.7	100
Chester	761	9.1	3.5	1.9	0.4	51.3	33.8	100
Delaware	191	28.7	9.2	6.0	1.7	15.3	39.1	100
Montgomery	496	21.1	6.0	3.6	1.4	38.0	29.9	100
Philadelphia	144	29.6	24.2	12.7	5.6	1.6	26.1	100
Pennsylvania total..........	2,217	15.7	6.0	3.7	1.4	35.9	37.3	100
Burlington	830	5.4	2.4	5.4	.3	23.8	62.8	100
Camden	224	18.7	8.3	3.8	1.4	16.6	51.2	100
Gloucester	339	9.0	3.3	2.1	1.0	33.9	50.6	100
Mercer	230	15.1	5.8	3.8	.9	39.4	34.6	100
New Jersey total..........	1,623	9.3	3.9	4.3	.7	27.2	54.7	100
Delaware Valley total..........	3,840	13.0	5.1	3.9	1.1	32.2	44.7	100

* Land use may not total 100 percent due to rounding off during compilation.

estuary. Manufacturing industries (primarily chemical, petroleum, and primary metals) constitute 1.1 percent (42 mi^2) of the Delaware Valley. Thirty-two percent (1,229 mi^2) of the Delaware Valley in 1970 was classified agricultural.

DATA COLLECTION

Sample Collection

Table 3 lists the sampling frequency of water and surficial bed material at the 13 sampling sites. Figure 1 shows the location of each site in the estuary.

Because saltwater is denser than freshwater, estuarine systems tend to stratify with depth near the zone of saltwater/ freshwater interface, causing the concentrations of many chemical constituents to stratify also. The water is additionally layered owing to temperature and density gradients, so that a representative sample must be integrated vertically and composited horizontally. Water and bed material samples are composites of three to five verticals along a single cross section at each site. Cross sections were selected along the tidal reach of each stream sampled.

All bed material samples were sieved through a 2-millimeter sieve at the time of collection. Water samples were collected with U.S. series point- and depth-integrating suspended-sediment samplers (Guy and Norman, 1970). Although most samples were collected during the outgoing part of the tidal cycle, some variances in water quality resulted from collecting the sample before all backwater had been flushed below the point of collection.

Water samples were collected for analysis of volatile organic compounds (table 4), acid and base/neutral extractable organic compounds (table 5), common ions, dissolved organic carbon, and trace metals. Bed material samples were collected for acid and base/neutral extractable organic compounds, pesticides (see table 9), and trace metals.

The samples for analysis of volatile organic compounds were collected in 40-milliliter glass septum bottles. Suspended sediment samplers were modified to collect a nonaerated sample. A length of tapered polyvinyl chloride tubing was friction fitted to the discharge side of the sampler's intake nozzle, and the other end was placed inside a septum bottle before it was loaded into the sampler (G. L. Pederson, written communication, 1980). These samples were sealed air tight and chilled at 4°C.

Samples for analysis of acid and base/neutral extractable organic compounds were collected in heat-treated glass bottles. These samples were also chilled at 4°C.

Table 3.--Sampling frequency and location of the 13 sampling sites.

Site No. (figure 1)	Site identification No.	Name	Latitude	Longitude	Date of sampling	
					Surface water	Bed material
1	01464560	Delaware River at Florence, N.J.	40°07'34"	074°48'59"	May 1980 Sep 1980 Nov 1980	May 1980
2	01464600	Delaware River at Bristol, Pa.	40°05'55"	074°51'58"	May 1980 Sep 1980 Nov 1980	May 1980
3	01467024	Rancocas Creek at Bridgeboro, N.J.	40°01'45"	074°55'55"	May 1980 Sep 1980 Nov 1980	May 1980
4	01467060	Delaware River at Palmyra, N.J.	40°01'05"	075°02'16"	May 1980 Sep 1980 Nov 1980	May 1980
5	01467082	Pennsauken Creek at Route 130, at Cinnaminson, N.J.	39°59'06"	075°00'55"	May 1980 Sep 1980 Nov 1980	May 1980
6	01467193	Cooper River below Federal Street at Camden, N.J.	39°56'42"	075°06'16"	May 1980 Sep 1980 Nov 1980	May 1980
7	01467200	Delaware River at Benjamin Franklin Bridge, at Philadelphia, Pa.	39°57'11"	075°08'05"	May 1980 Sep 1980 Nov 1980	May 1980
8	01467390	Big Timber Creek at Westville, N.J.	39°52'28"	075°07'36"	Nov 1980	
9	01475160	Mantua Creek at Paulsboro, N.J.	39°49'52"	075°14'13"	Nov 1980	
10	01475200	Delaware River at Paulsboro, N.J.	39°50'42"	075°16'10"	May 1980 Sep 1980 Nov 1980	May 1980
11	01477160	Raccoon Creek at Bridgeport, N.J.	39°48'04"	075°21'22"	May 1980 Sep 1980 Nov 1980	May 1980 Jan 1981
12	01477600	Oldmans Creek at Nortonville, N.J.	39°47'05"	075°24'25"	Nov 1980	
13	01482100	Delaware River at Delaware Memorial Bridge, at Wilmington, Del.	39°41'21"	075°31'19"	May 1980 Sep 1980 Nov 1980	May 1980

Table 4.--U.S. Environmental Protection Agency priority pollutants: analysis list of specific volatile organic compounds detectable* by the U.S. Geological Survey Central Laboratory.

*Results are semiquantitative.

Source: Beetem and others (eds.), 1980.

<u>Volatile Organic Compounds</u>

Benzene
Bromoform
Carbon tetrachloride
Chlorobenzene
Chlorodibromomethane
Chloroethane
2-Chloroethyl vinyl ether
Chloroform
Dichlorobromomethane
Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethylene
1,2-*trans*-dichloroethylene
1,2-Dichloropropane
1,3-Dichloropropene
Ethylbenzene
Methylbromide
Methylene chloride
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Toluene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Trichlorofluoromethane
Vinyl chloride

Table 5.--U.S. Environmental Protection Agency priority pollutants: analysis list of acid extractable and base/neutral extractable organic compounds.

Note: Components quantified if concentration exceeds 2.0 µg/kg (bed material) or 1.0 µg/L (water phase). Detection and identification of compounds will depend on many factors and will be strongly affected by the total composition of the sample and by compound concentration.

Source: Beetem and others (eds.), 1980.

Acid Extractable Organic Compounds

4-Chloro-3-methylphenol
2-Chlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
4,6-Dinitro-2-methylphenol
2,4-Dinitrophenol
2-Nitrophenol
4-Nitrophenol
Pentachlorophenol
Phenol
2,4,6-Trichlorophenol

Base/Neutral Extractable Organic Compounds

Acenaphthene
Acenaphthylene
Anthracene
Benzidine
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(g,h,i)perylene
Benzo(a)pyrene
4-Bromophenyl phenyl ether
Butyl benzyl phthalate
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
2-Chloronaphthalene
4-Chlorophenyl phenyl ether
Chrysene
Dibenzo(a,h)anthracene
Di-n-butyl phthalate
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
3,3'-Dichlorobenzidine
Diethyl phthalate
Dimethyl phthalate
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Di-n-octylphthalate
Bis(2-ethylhexyl)phthalate
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Naphthalene
Nitrobenzene
Nitrosodimethylamine
n-Nitrosodiphenylamine
n-Nitrosodi-n-propylamine
Phenanthrene
Pyrene
2,3,7,8-Tetrachlorodibenzo-p-dioxin
1,2,4-Trichlorobenzene

Temperature, specific conductance, pH, alkalinity, and bicarbonate were determined in the field. Samples for analysis of dissolved organic carbon were filtered through a 0.45-micrometer silver filter into heat-treated glass bottles. Samples for metals analysis were acidified with nitric acid to pH 2.0 or below. The samples analyzed for nitrogen, phosphorous, dissolved organic carbon, and bed material content were stored at 4°C.

Laboratory Methodology

The U.S. Geological Survey National Water Quality Laboratory in Doraville, Ga. performed all laboratory analyses. Potassium, phosphorus, nitrate and nitrite nitrogen, sulfate, and chloride were analyzed by laboratory methods described by Skougstad and others (1979). Dissolved organic carbon was analyzed by a wet oxidation method described by Goerlitz and Brown (1972).

Volatile organic compounds were analyzed on a gas chromatography/mass spectrometry (GC-MS) system using a "vapor stripping" technique (U.S. Environmental Protection Agency, 1979a). Acid and base/neutral extractable organic compounds were analyzed by EPA method 625 on a GC-MS. Each sample was extracted with methylene chloride within 48 hours of receipt at the laboratory. Insecticides and polychlorinated biphenyls were analyzed on a gas chromatograph utilizing an electron capture detector (U.S. Environmental Protection Agency, 1979b). The PCB analysis includes all nondifferentiated Arochlor[1] compounds. All trace metal analyses were performed by induction coupled plasma spectrometry (Garbarino and Taylor, 1979).

RESULTS

Water Quality

Table 6 contains the results of chemical analyses collected from the 13 sampling sites. Nitrite and nitrate nitrogen (NO_2 and NO_3) concentrations ranged from 0.03 mg/L to 2.5 mg/L and were within maximum levels for domestic water supply as established by U.S. EPA (1977, p. 107).

Figure 3 shows the major ion distribution in samples collected at five sites along the Delaware River estuary during September 1980. The September sampling was chosen because all the samples were collected during the same approximate segment of the tidal cycle. As the water travels downstream, its composition quickly changes within the saltwater/freshwater mixing zone from a moderately predominate calcium bicarbonate type to a predominately sodium-potassium chloride type. Maximum concentrations of chloride (2,200 mg/L) as well as sulfate (390 mg/L) were measured

[1] The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Table 6.--Chemical analyses of selected surface-water sites in the Delaware River estuary.

Date	Time	Direction of tide	Temperature, water (deg C)	Specific conductance (µmho/cm)	pH field (units)	Carbon dioxide dissolved (mg/L as CO_2)	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate (mg/L as HCO_3)	Nitrogen NO_2+NO_3 dissolved (mg/L as N)	Phosphorus, orthophosphate dissolved (mg/L as PO_4)	Phosphorus, orthophosphate dissolved (mg/L as P)
01464560 - Delaware River at Florence, N.J.											
May 21, 1980	1240	Outgoing	--	181	7.4	3.3	44	54	1.5	0.09	0.03
Sep 4	1515	--do--	--	230	7.3	5.2	53	65	1.2	.15	.05
Nov 25	0940	--do--	7.5	226	7.4	3.9	50	61	1.4	.00	.00
01464600 - Delaware River at Bristol, Pa.											
May 21, 1980	1050	Outgoing	--	176	7.2	5.0	41	50	1.5	.06	.02
Sep 4	1440	--do--	--	242	7.4	3.8	48	59	1.4	.15	.05
Nov 25	1040	--do--	7.0	238	7.6	2.5	50	61	1.3	.95	.31
01467024 - Rancocas Creek at Bridgeboro, N.J.											
May 20, 1980	1345	Outgoing	--	100	6.5	7.0	10	12	.96	.28	.09
Sep 4	1345	--do--	--	250	7.6	2.3	48	58	1.3	.18	.06
Nov 14	1425	Low Slack/ Incoming	8.0	178	6.9	3.8	16	19	1.0	.00	.00
01467060 - Delaware River at Palmyra, N.J.											
May 21, 1980	1150	Outgoing	--	168	7.2	4.5	37	45	1.7	.09	.03
Sep 4	1300	--do--	--	274	7.2	6.0	48	59	1.5	.34	.11
Nov 25	1210	Incoming	7.5	238	7.2	6.2	50	61	1.5	.21	.07
01467082 - Pennsauken Creek at Rt 130, at Cinnaminson, N.J.											
May 21, 1980	0940	Outgoing	--	185	6.8	12	39	48	1.7	.12	.04
Sep 4	1210	--do--	--	269	7.4	4.6	60	73	1.4	.31	.10
Nov 14	1330	Low Slack	8.9	422	7.1	13	82	100	1.8	2.3	.74
01467193 - Cooper River below Federal Street, at Camden, N.J.											
May 20, 1980	1320	Outgoing	--	304	7.2	6.9	60	73	.76	.40	.13
Sep 3	1300	--do--	--	336	7.3	6.7	68	83	.96	.40	.13
Nov 14	1230	--do--	8.1	317	7.2	8.2	66	81	1.2	.03	.01
01467200 - Delaware River at Benjamin Franklin Bridge, at Philadelphia, Pa.											
May 23, 1980	1400	Outgoing	--	206	7.1	6.5	42	51	1.0	.31	.10
Sep 3	1220	--do--	--	331	6.8	14	46	56	1.6	.00	.00
Nov 25	1320	Incoming	7.5	305	7.3	4.9	50	61	1.5	.37	.12
01467390 - Big Timber Creek at Westville, N.J.											
Nov 14, 1980	1130	Outgoing	8.9	313	6.7	16	42	51	1.8	.00	.00
01475160 - Mantua Creek at Paulsboro, N.J.											
Nov 14, 1980	1010	Outgoing	8.5	420	6.8	11	36	44	1.7	.00	.00
01475200 - Delaware River at Paulsboro, N.J.											
May 22, 1980	1100	Outgoing	--	254	7.1	6.1	35	43	.03	.37	.12
Sep 3	1120	--do--	--	749	6.8	13	42	51	2.4	.00	.00
Nov 26	1045	--do--	8.0	459	7.1	7.8	50	61	1.8	.15	.05
01477160 - Raccoon Creek at Bridgeport, N.J.											
May 23, 1980	1130	Outgoing	--	228	7.5	2.0	34	42	1.4	.21	.07
Sep 3	1020	--do--	--	148	7.2	5.7	46	56	2.5	.06	.02
Nov 17	1405	--do--	5.9	1091	7.0	8.0	41	50	2.4	.03	.01
01477600 - Oldmans Creek at Nortonville, N.J.											
Nov 17, 1980	1250	Outgoing	5.9	1970	6.9	8.1	33	40	2.5	.00	.00
01482100 - Delaware River at Delaware Memorial Bridge, at Wilmington, Del.											
May 22, 1980	0855	Outgoing	--	413	7.1	4.7	30	37	.42	.00	.00
Sep 3	0845	--do--	--	6800	7.4	3.8	49	60	2.5	--	--
Nov 26	1245	Incoming	7.2	6060	7.7	1.9	50	61	2.5	.06	.02

Table 6.--Chemical analyses of selected surface-water sites in the Delaware River estuary--Continued

Date	Carbon, organic dis-solved (mg/L as C)	Hard-ness (mg/L as $CaCO_3$)	Hard-ness, noncar-bonate (mg/L as $CaCO_3$)	Calcium dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Sodium ad-sorp-tion ratio	Sodium (percent)	Potas-sium, dis-solved (mg/L as K)	Chlo-ride, dis-solved (mg/L as Cl)
01464560 - Delaware River at Florence, N.J.										
May 21, 1980	6.2	62	18	15	5.9	10	0.6	--	--	12
Sep 4	2.8	78	25	19	7.3	13	.7	26	2.4	17
Nov 25	2.6	78	28	20	6.9	15	.8	29	2.1	17
01464600 - Delaware River at Bristol, Pa.										
May 21, 1980	4.6	57	16	14	5.4	10	.6	--	--	11
Sep 4	2.8	81	33	20	7.6	15	.8	28	2.6	19
Nov 25	3.6	78	28	20	6.9	15	.8	29	2.2	20
01467024 - Rancocas Creek at Bridgeboro, N.J.										
May 20, 1980	14	26	16	6.7	2.2	7.7	.7	--	--	9.4
Sep 4	3.5	330	280	19	68	16	.5	10	2.9	20
Nov 14	3.6	41	25	11	3.3	12	.9	36	3.6	17
01467060 - Delaware River at Palmyra, N.J.										
May 20, 1980	5.4	56	19	14	5.2	10	.6	--	--	11
Sep 4	3.6	80	32	20	7.3	18	.9	32	3.2	23
Nov 25	6.2	81	31	21	6.8	15	.8	28	2.6	21
01467082 - Pennsauken Creek at Rt 130, at Cinnaminson, N.J.										
May 20, 1980	5.2	57	18	14	5.3	13	.8	--	--	14
Sep 4	3.4	79	19	20	7.1	19	1.0	33	3.5	23
Nov 14	6.0	86	4	24	6.3	40	2.0	47	9.8	50
01467193 - Cooper River below Federal Street, at Camden, N.J.										
May 23, 1980	11	62	2	17	4.8	20	1.2	39	4.9	21
Sep 3	7.4	77	9	20	6.5	33	1.8	46	6.5	32
Nov 14	6.1	70	4	19	5.3	23	1.3	39	7.9	30
01467200 - Delaware River at Benjamin Franklin Bridge, at Philadelphia, Pa.										
May 23, 1980	8.5	61	19	16	5.1	11	.7	27	2.0	13
Sep 3	5.2	92	46	23	8.4	25	1.2	36	4.0	36
Nov 25	4.9	87	37	22	7.8	24	1.2	36	3.8	34
01467390 - Big Timber Creek at Westville, N.J.										
Nov 14, 1980	13	75	33	19	6.7	25	1.4	40	5.7	35
01475160 - Mantua Creek at Paulsboro, N.J.										
Nov 14, 1980	9.9	95	59	22	9.6	41	2.0	47	5.6	64
01475200 - Delaware River at Paulsboro, N.J.										
May 22, 1980	2.5	68	33	17	6.1	15	.9	32	2.2	17
Sep 3	4.8	130	88	27	16	97	4.1	60	7.5	160
Nov 26	5.4	120	70	28	11	39	1.7	41	5.2	68
01477160 - Raccoon Creek at Bridgeport, N.J.										
May 23, 1980	6.0	69	35	18	5.9	14	.8	30	2.2	19
Sep 3	5.9	200	150	30	30	260	9.2	72	13	500
Nov 17	5.2	160	120	28	21	160	6.3	67	9.8	250
01477600 - Oldmans Creek at Nortonville, N.J.										
Nov 17, 1980	4.0	230	200	34	35	310	10	73	16	420
01482100 - Delaware River at Delaware Memorial Bridge, at Wilmington, Del.										
May 22, 1980	2.8	81	51	17	9.4	52	2.8	57	3.4	77
Sep 3	3.9	--	--	--	--	--	--	--	--	2200
Nov 26	5.8	550	500	54	100	960	21	78	41	1700

Table 6.--Chemical analyses of selected surface-water sites in the Delaware River estuary--Continued

Date	Sulfate dissolved (mg/L as SO_4)	Silica, dissolved (mg/L as SiO_2)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium dissolved (µg/L as Cd)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)
01464560 - Delaware River at Florence, N.J.									
May 21, 1980	26	3.2	40	3	3	<3	<10	100	<10
Sep 4	28	1.2	30	<1	<1	<3	<10	10	<10
Nov 25	33	1.6	30	<1	--	<3	<10	160	<10
01464600 - Delaware River at Bristol, Pa.									
May 21, 1980	24	3.2	30	<1	3	<3	<10	63	--
Sep 4	30	.1	30	<1	1	<3	<10	8	<10
Nov 25	35	1.9	20	<1	--	<3	<10	88	<10
01467024 - Rancocas Creek at Bridgeboro, N.J.									
May 20, 1980	18	5.2	40	<1	<1	<3	15	1300	<10
Sep 4	31	.3	30	<1	<1	<3	<10	56	<10
Nov 14	33	7.7	30	<1	<1	<3	<10	57	<10
01467060 - Delaware River at Palmyra, N.J.									
May 20, 1980	24	3.9	40	<1	2	<3	12	81	<10
Sep 4	37	.1	30	<1	2	<3	<10	21	<10
Nov 25	37	2.9	40	<1	--	<3	<10	66	<10
01467082 - Pennsauken Creek at Rt 130, at Cinnaminson, N.J.									
May 20, 1980	26	4.0	30	<1	3	<3	18	96	<10
Sep 4	33	.7	30	<1	1	<3	10	29	<10
Nov 14	41	12	30	<1	2	<3	16	33	<10
01467193 - Cooper River below Federal Street, at Camden, N.J.									
May 23, 1980	31	7.5	40	<1	<1	<3	<10	130	--
Sep 3	42	4.6	30	2	1	<3	<10	110	<10
Nov 14	38	10	30	1	1	<3	<10	85	<10
01467200 - Delaware River at Benjamin Franklin Bridge, at Philadelphia, Pa.									
May 23, 1980	26	3.2	30	<1	<1	<3	<10	58	<10
Sep 3	53	.4	40	<1	2	<3	<10	55	<10
Nov 25	48	3.6	30	<1	--	<3	<10	78	<10
01467390 - Big Timber Creek at Westville, N.J.									
Nov 14, 1980	45	5.8	30	1	<1	<3	<10	40	<10
01475160 - Mantua Creek at Paulsboro, N.J.									
Nov 14, 1980	54	3.9	40	1	<1	<3	<10	89	<10
01475200 - Delaware River at Paulsboro, N.J.									
May 22, 1980	39	2.5	30	<1	<1	<3	<10	64	<10
Sep 3	81	.5	40	<1	1	<3	<10	18	<10
Nov 26	71	3.2	30	<1	--	<3	<10	54	<10
01477160 - Raccoon Creek at Bridgeport, N.J.									
May 23, 1980	36	.2	30	<1	<1	<3	<10	88	--
Sep 3	110	.3	40	<1	2	<3	<10	13	<10
Nov 17	89	4.0	40	<1	1	<3	<10	55	<10
01477600 - Oldmans Creek at Nortonville, N.J.									
Nov 17, 1980	110	3.4	50	<1	4	<3	<10	47	<10
01482100 - Delaware River at Delaware Memorial Bridge, at Wilmington, Del.									
May 22, 1980	41	.2	30	<1	<1	<3	<10	28	--
Sep 3	390	--	--	--	--	--	--	--	--
Nov 26	320	1.8	40	<1	--	<3	10	7	15

Table 6.--Chemical analyses of selected surface-water sites in the Delaware River estuary--Continued

Date	Manganese, dissolved (µg/L as Mn)	Molybdenum, dissolved (µg/L as Mo)	Strontium, dissolved (µg/L as Sr)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)	Lithium dissolved (µg/L as Li)	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Solids, dissolved (tons per ac-ft)
01464560 - Delaware River at Florence, N.J.									
May 21, 1980	46	<10	65	<6.0	21	<4	119	106	0.16
Sep 4	22	<10	87	<6.0	<4	<4	146	126	.20
Nov 25	83	<10	78	<6.0	33	4	491	132	.67
01464600 - Delaware River at Bristol, Pa.									
May 21, 1980	27	18	63	<6.0	18	<4	110	99	.15
Sep 4	11	<10	90	<6.0	<4	<4	147	130	.20
Nov 25	94	<10	79	<6.0	20	<4	140	138	.19
01467024 - Rancocas Creek at Bridgeboro, N.J.									
May 20, 1980	71	<10	39	<6.0	34	<4	72	61	.10
Sep 4	4	<10	91	<6.0	<4	<4	150	192	.20
Nov 14	47	<10	64	<6.0	6	4	107	102	.15
01467060 - Delaware River at Palmyra, N.J.									
May 20, 1980	25	<10	63	<6.0	14	<4	112	98	.15
Sep 4	20	<10	97	<6.0	5	<4	162	145	.22
Nov 25	37	<10	86	<6.0	12	5	147	144	.20
01467082 - Pennsauken Creek at Rt 130, at Cinnaminson, N.J.									
May 20, 1980	41	<10	80	<6.0	10	<4	117	108	.16
Sep 4	23	<10	110	<6.0	5	<4	170	149	.23
Nov 14	120	<10	280	<6.0	14	12	256	243	.35
01467193 - Cooper River below Federal Street, at Camden, N.J.									
May 20, 1980	81	<10	170	<6.0	14	7	160	146	.22
Sep 3	68	<10	190	<6.0	<4	5	210	191	.29
Nov 14	77	<10	250	<6.0	7	6	184	179	.25
01467200 - Delaware River at Benjamin Franklin Bridge, at Philadelphia, Pa.									
May 23, 1980	33	21	72	<6.0	15	<4	117	106	.16
Sep 3	110	<10	110	<6.0	<4	4	190	185	.26
Nov 25	98	<10	98	<6.0	19	4	185	181	.25
01467390 - Big Timber Creek at Westville, N.J.									
Nov 14, 1980	110	<10	120	<6.0	14	5	194	176	.26
01475160 - Mantua Creek at Paulsboro, N.J.									
Nov 14, 1980	140	<10	110	<6.0	14	6	251	230	.34
01475200 - Delaware River at Paulsboro, N.J.									
May 22, 1980	50	12	83	<6.0	19	4	141	121	.19
Sep 3	120	<10	180	<6.0	<4	7	454	425	.62
Nov 26	190	<10	140	<6.0	32	5	283	264	.38
01477160 - Raccoon Creek at Bridgeport, N.J.									
May 23, 1980	52	<10	82	<6.0	14	6	134	123	.18
Sep 3	84	<10	270	<6.0	<4	11	874	982	1.19
Nov 17	190	<10	190	<6.0	7	8	591	598	.80
01477600 - Oldmans Creek at Nortonville, N.J.									
Nov 17, 1980	320	<10	300	<6.0	10	11	1060	960	1.44
01482100 - Delaware River at Delaware Memorial Bridge, at Wilmington, Del.									
May 22, 1980	25	29	99	<6.0	13	6	250	220	.34
Sep 3	--	--	--	--	--	--	--	--	--
Nov 26	120	<10	760	11	21	6	3320	3220	4.52

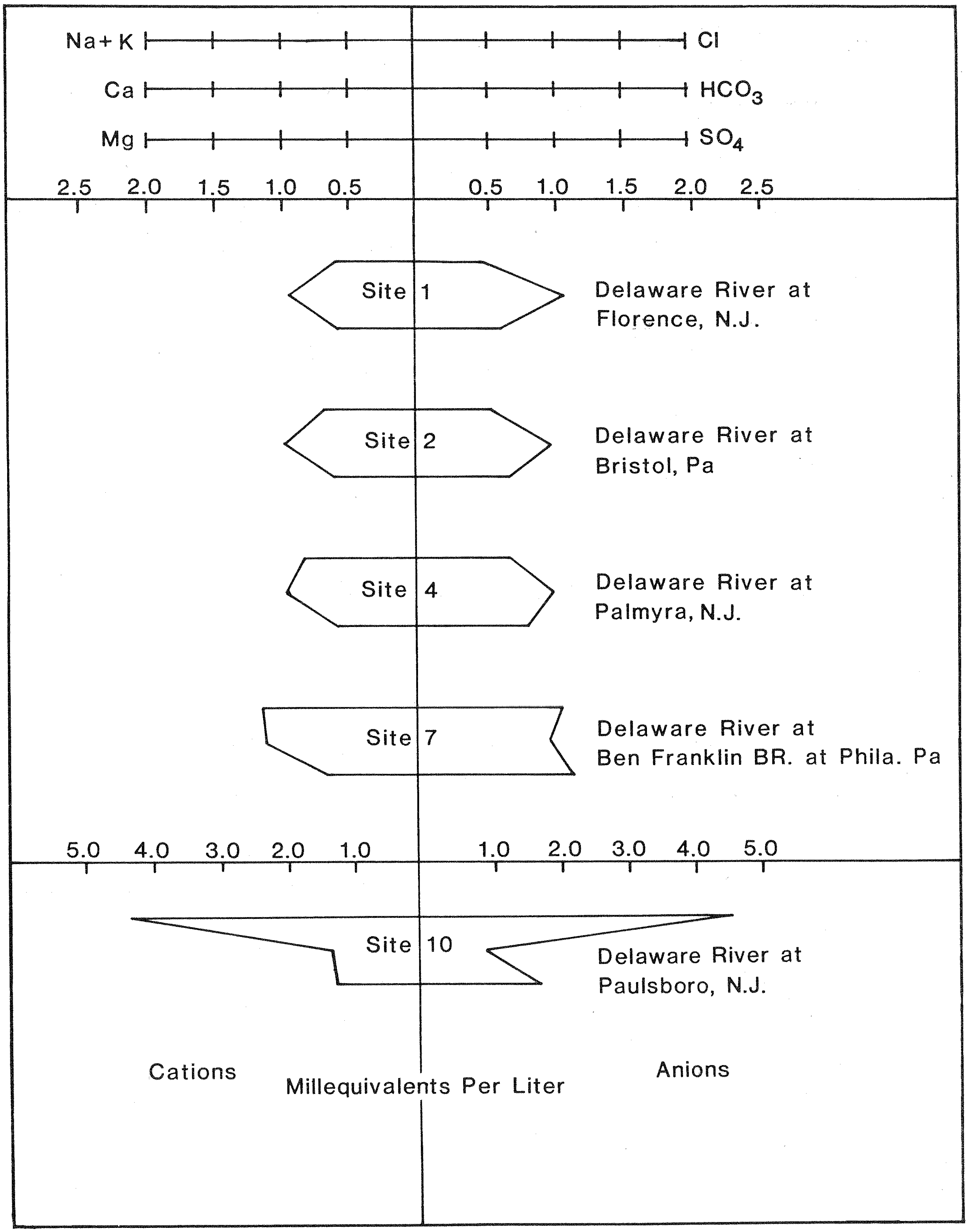


Figure 3.--Stiff diagrams of major ions at five Delaware River estuary sampling locations, September 3-4, 1980.

in the Delaware River at Delaware Memorial Bridge at Wilmington, Del. These analyses are not represented in figure 3, however, because no cation concentrations were recorded for this site in September.

The maximum dissolved iron concentration (1,300 μg/L) was recorded at Rancocas Creek at Bridgeboro, N.J., in May 1980. The median concentration for dissolved iron was 57 μg/L.

Table 7 shows the analyses of volatile organic compounds in the surface water. Benzene, toluene, cyclohexanes, trichloroethylene, and tetrachloroethylene are the predominant compounds detected in the estuary. Samples contained traces of 1,1-dichloropropane only in September 1980 in the vicinity of Philadelphia. Throughout the study, about 60 percent of the surface-water samples contained at least some measurable amount of volatile organic compounds, at concentrations ranging from 1.0 μg/L to 12.4 μg/L for each constituent identified. About 15 percent of all samples contained a 20-50 μg/L background of undifferentiated hydrocarbons, including cyclohexanes.

In November 1980, samples from 13 sites were analyzed for acid and base/neutral extractable organic compounds. These semiquantitative analyses showed no recoverable concentrations of any acid or base/neutral extractable organic compounds at the 2 μg/L detection limit. Since these samples represent only one sampling, it is believed that these semiquantitative results may not accurately reflect the actual conditions present in the estuary.

Sediment Quality

Table 8 contains chemical analyses of the surficial bed material at 10 locations, including results for trace metals, organochlorine and organophosphorous insecticides, and PCB's. The maximum concentrations for most constituents were in the first of two samples taken from Raccoon Creek at Bridgeport, N.J. Cadmium, chromium, cobalt, and diazinon were only found in the surficial bed material at this site, while high relative concentrations of copper, lead, and zinc were also found here. Although trace metals were not resampled, significantly lower values for insecticides and PCB's were recorded during a second sampling of Raccoon Creek at a different cross section.

The most common chlorinated organic compounds in the bed material were DDD, DDE, PCB's, DDT, and chlordane. Figures 4 through 6 plot concentrations of DDT and its metabolites, chlordane, and PCB's, respectively, in the bed material of all 10 sites sampled. The bed material at the Delaware River at Palmyra contained the maximum recoverable concentrations of DDT-T and PCB's in the estuary; whereas the minimum concentrations for these constituents were found in the bed material of the Delaware River at Benjamin Franklin Bridge at Philadelphia. The only value

Table 7.--Analyses of volatile organic compounds in the surface water of the Delaware River estuary.

N.D. None detected at the minimum detection limit.

S.D. Sample destroyed.

Site identification No.	Date	Time	Compound(s) detected	Concentration (µg/L)
01464560	5-21-80	1240	N.D.	
	9-04-80	1515	N.D.	
	11-25-80	0940	Benzene*	12.0
01464600	5-21-80	1050	Trichloroethylene	5.0
	9-04-80	1440	N.D.	
	11-25-80	1040	*	
01467024	5-20-80	1345	Trichloroethylene	5.0
	9-04-80	1345	N.D.	
	11-14-80	1425	Toluene	1.0
01467060	5-20-80	1150	Trichloroethylene	5.0
	9-04-80	1300	N.D.	
	11-25-80	1210	*	
01467082	5-20-80	0940	Trichloroethylene	5.0
	9-04-80	1210	N.D.	
	11-14-80	1330	Trichloroethylene	2.0
			Toluene	2.0
01467193	5-23-80	1320	Tetrachloroethylene	8.0
	9-03-80	1300	N.D.	
	11-14-80	1230	Toluene	1.0
01467200	5-23-80	1400	S.D.	
	9-03-80	1220	1,1-Dichloropropane	5.0
	11-25-80	1320	*	
01467390	11-14-80	1130	S.D.	
01475160	11-14-80	1010	N.D.	
01475200	5-22-80	1100	N.D.	
01475200	5-22-80	1100	N.D.	
	9-03-80	1120	1,1-Dichloropropane	3.0
	11-26-80	1045	S.D.	
01477160	5-23-80	1130	S.D.	
	9-03-80	1020	N.D.	
	11-17-80	1405	Benzene	1.4
01477600	11-17-80	1250	Benzene	1.5
			Toluene	1.7
01482100	5-22-80	0855	S.D.	
	9-03-80	0845	N.D.	
	11-26-80	1245	Toluene*	10.0

* Undifferentiated hydrocarbons including cyclohexanes (approximately 20-50 µg/L).

Table 8.--Chemical analyses of surficial bed material in the Delaware River estuary.

Date	Time	Arsenic total (μg/g as As)	Cadmium recov-erable (μg/g as Cd)	Chro-mium, recov-erable (μg/g)	Cobalt, recov-erable (μg/g as Co)	Copper, recov-erable (μg/g as Cu)	Iron, recov-erable (μg/g as Fe)	Lead, recov-erable (μg/g as Pb)	Manga-nese, recov-erable (μg/g)	Mercury recov-erable (μg/g as Hg)	Zinc, recov-erable (μg/g as Zn)	Sele-nium, total (μg/g)
01464560 - Delaware River at Florence, N.J.												
May 21, 1980	1240	3	<10	30	10	30	39000	60	650	0.00	430	1
01464600 - Delaware River at Bristol, Pa.												
May 21, 1980	1050	0	<10	<10	10	<10	5600	10	270	.00	110	0
01467024 - Rancocas Creek at Bridgeboro, N.J.												
May 20, 1980	1345	0	<10	<10	<10	<10	9500	20	130	.00	55	0
01467060 - Delaware River at Palmyra, N.J.												
May 20, 1980	1150	0	<10	30	<10	70	12000	150	580	.02	530	0
01467082 - Pennsauken Creek at Rt 130, at Cinnaminson, N.J.												
May 20, 1980	0940	2	<10	<10	<10	<10	12000	<10	45	.00	12	0
01467193 - Cooper River below Federal Street, at Camden, N.J.												
May 23, 1980	1320	1	<10	<10	<10	<10	2600	40	83	.00	270	0
01467200 - Delaware River at Benjamin Franklin Bridge, at Philadelphia, Pa.												
May 23, 1980	1400	1	<10	<10	10	<10	6300	40	820	.00	350	0
01475200 - Delaware River at Paulsboro, N.J.												
May 22, 1980	1100	2	<10	30	30	10	21000	30	710	.00	74	0
01477160 - Raccoon Creek at Bridgeport, N.J.												
May 23, 1980	1130	4	20	190	50	230	29000	590	500	.01	2100	0
Jan 8, 1981	1100	--	--	--	--	--	--	--	--	--	--	--
01482100 - Delaware River at Delaware Memorial Bridge, at Wilmington, Del.												
May 22, 1980	0855	4	<10	<10	30	20	23000	60	940	.00	91	0

Date	Aldrin, total (μg/kg)	Lindane total (μg/kg)	Chlor-dane, total (μg/kg)	Mirex, total (μg/kg)	Per-thane (μg/kg)	DDD, total (μg/kg)	DDE, total (μg/kg)	DDT, total (μg/kg)	Diel-drin, total (μg/kg)	Endo-sulfan, total (μg/kg)	Endrin, total (μg/kg)	Ethion, total (μg/kg)
01464560 - Delaware River at Florence, N.J.												
May 21, 1980	<0.1	<0.1	4	<0.1	<0.1	7.4	10	4.4	<0.1	<0.1	<0.1	<0.1
01464600 - Delaware River at Bristol, Pa.												
May 21, 1980	<.1	<.1	<1	<.1	<.1	23	14	28	<.1	<.1	<.1	<.1
01467024 - Rancocas Creek at Bridgeboro, N.J.												
May 20, 1980	<.1	<.1	2	<.1	<.1	1.9	2.4	.5	.1	<.1	<.1	<.1
01467060 - Delaware River at Palmyra, N.J.												
May 20, 1980	<.1	<.1	21	<.1	510	94	210	45	1.2	.1	<.1	<.1
01467082 - Pennsauken Creek at Rt 130, at Cinnaminson, N.J.												
May 20, 1980	<.1	<.1	16	<.1	<.1	18	.8	.2	1.0	.2	<.1	<.1
01467193 - Cooper River below Federal Street, at Camden, N.J.												
May 23, 1980	<.1	<.1	<1	<.1	<.1	5.8	7.4	<.1	<.1	<.1	<.1	<.1
01467200 - Delaware River at Benjamin Franklin Bridge, at Philadelphia, Pa.												
May 23, 1980	<.1	<.1	<1	<.1	<.1	2.1	1.8	<.1	<.1	<.1	<.1	<.1
01475200 - Delaware River at Paulsboro, N.J.												
May 22, 1980	<.1	<.1	5	<.1	<.1	32	23	1.4	.3	<.1	<.1	<.1
01477160 - Raccoon Creek at Bridgeport, N.J.												
May 23, 1980	<.1	<.1	190	<.1	<.1	4000	300	150	10	<.1	<.1	<.1
Jan 8, 1981	<.1	<.1	2	<.1	<.1	3.9	1.6	<.1	.3	<.1	<.1	--
01482100 - Delaware River at Delaware Memorial Bridge, at Wilmington, Del.												
May 22, 1980	<.1	<.1	7	<.1	<1	12	10	<.1	<.1	<.1	<.1	<.1

Table 8.--Chemical analyses of surficial bed material in the Delaware River estuary--Continued

Date	Toxaphene, total (µg/kg)	Heptachlor, total (µg/kg)	Heptachlor epoxide total (µg/kg)	Methoxychlor, total (µg/kg)	PCB, total (µg/kg)	PCN, total (µg/kg)	Malathion, total (µg/kg)	Parathion, total (µg/kg)	Diazinon, total (µg/kg)	Methyl parathion, total (µg/kg)	Trithion, total (µg/kg)	Methyl trithion, total (µg/kg)
01464560 - Delaware River at Florence, N.J.												
May 21, 1980	<1	<0.1	<0.1	<0.1	55	<1	<0.1	<0.1	<0.1	<0.1	<10	<0.1
01464600 - Delaware River at Bristol, Pa.												
May 21, 1980	<1	<.1	<.1	<.1	32	<1	<.1	<.1	<.1	<.1	<10	<.1
01467024 - Rancocas Creek at Bridgeboro, N.J.												
May 20, 1980	<1	<.1	<.1	<.1	3	<1	<.1	<.1	<.1	<.1	<10	<.1
01467060 - Delaware River at Palmyra, N.J.												
May 20, 1980	<1	<.1	<.1	<.1	190	<1	<.1	<.1	<.1	<.1	<10	<.1
01467082 - Pennsauken Creek at Rt 130, at Cinnaminson, N.J.												
May 20, 1980	<1	<.1	.4	<.1	<1	<1	<.1	<.1	<.1	<.1	<10	<.1
01467193 - Cooper River below Federal Street, at Camden, N.J.												
May 23, 1980	<1	<.1	<.1	<.1	6	<1	<.1	<.1	<.1	<.1	<10	<.1
01467200 - Delaware River at Benjamin Franklin Bridge, at Philadelphia, Pa.												
May 23, 1980	<1	<.1	<.1	<.1	2	<1	<.1	<.1	<.1	<.1	<10	<.1
01475200 - Delaware River at Paulsboro, N.J.												
May 22, 1980	<1	<.1	<.1	<.1	62	<1	<.1	<.1	<.1	<.1	<10	<.1
01477160 - Raccoon Creek at Bridgeport, N.J.												
May 23, 1980	<1	<.1	1.6	<.1	830	<1	<.1	<.1	1.6	<.1	<10	<.1
Jan 8, 1981	<1	<.1	<.1	<.1	11	<1	--	--	--	--	--	--
01482100 - Delaware River at Delaware Memorial Bridge, at Wilmington, Del.												
May 22, 1980	<1	<.1	<.1	<.1	42	<1	<.1	<.1	<.1	<.1	<10	<.1

recorded in 1980 for perthane was 510 µg/kg in the bed material of the Delaware River at Palmyra.

Table 9 separates insecticides detected at one or more locations from those not found at any location. The only organophosphorous insecticide detected in the bed material of the region was diazinon (1.6 µg/kg), which was found at Raccoon Creek at Bridgeport.

Table 9.--Insecticides for which analyses were done on most surficial bed material samples.

Detected at one or more locations	Not detected at any location
Chlordane	Aldrin
DDD	Lindane
DDE	Endrin
DDT	Malathion
Diazinon	Ethion
Dieldrin	Toxaphene
Endosulfan	Heptachlor
Heptachlorepoxide	Mirex
Perthane	Methoxychlor
	Parathion
	Methylparathion
	Trithion
	Methyltrithion

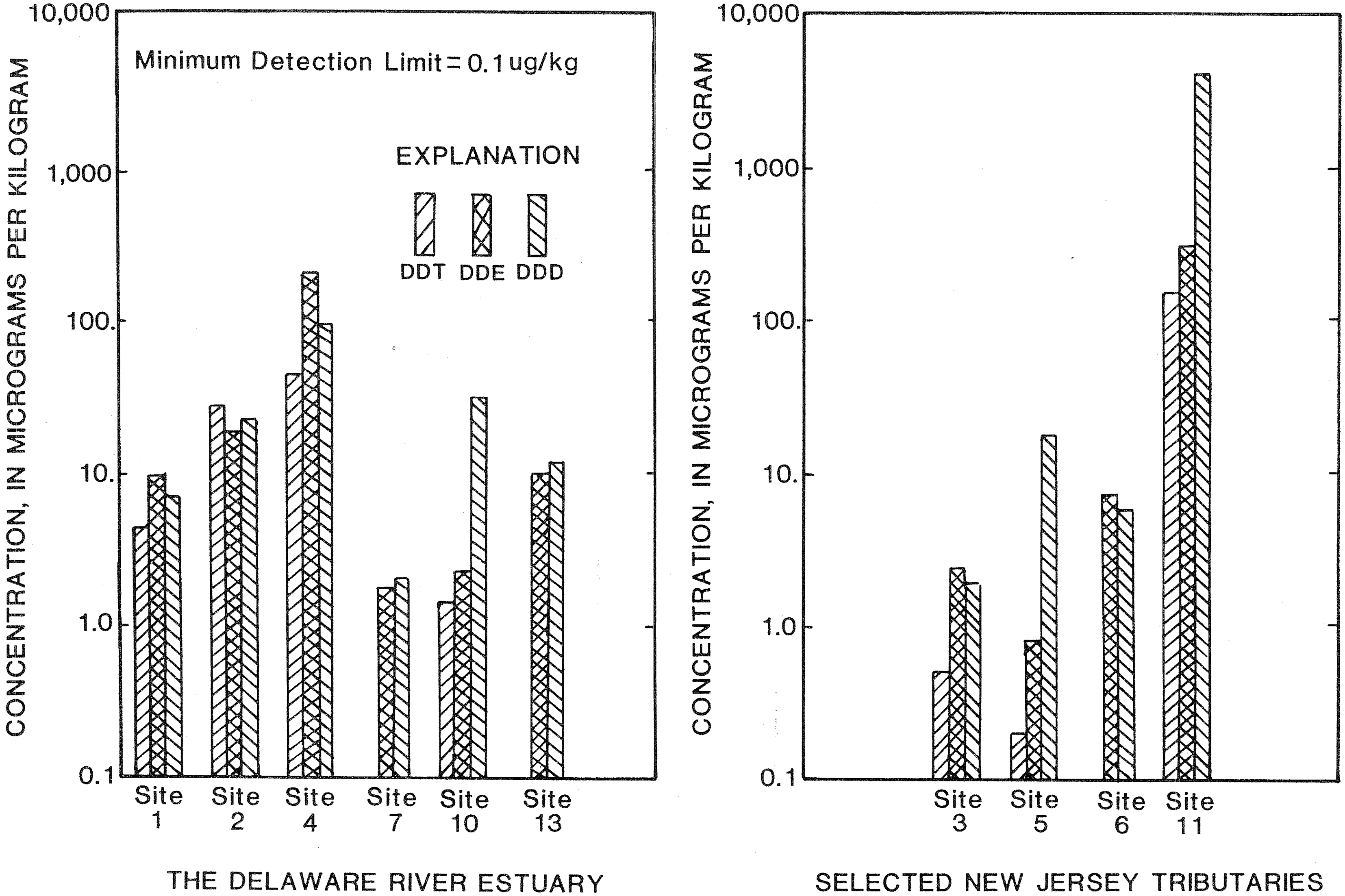


Figure 4.--Concentration of DDT and its metabolites in the surficial bed material of selected sites.

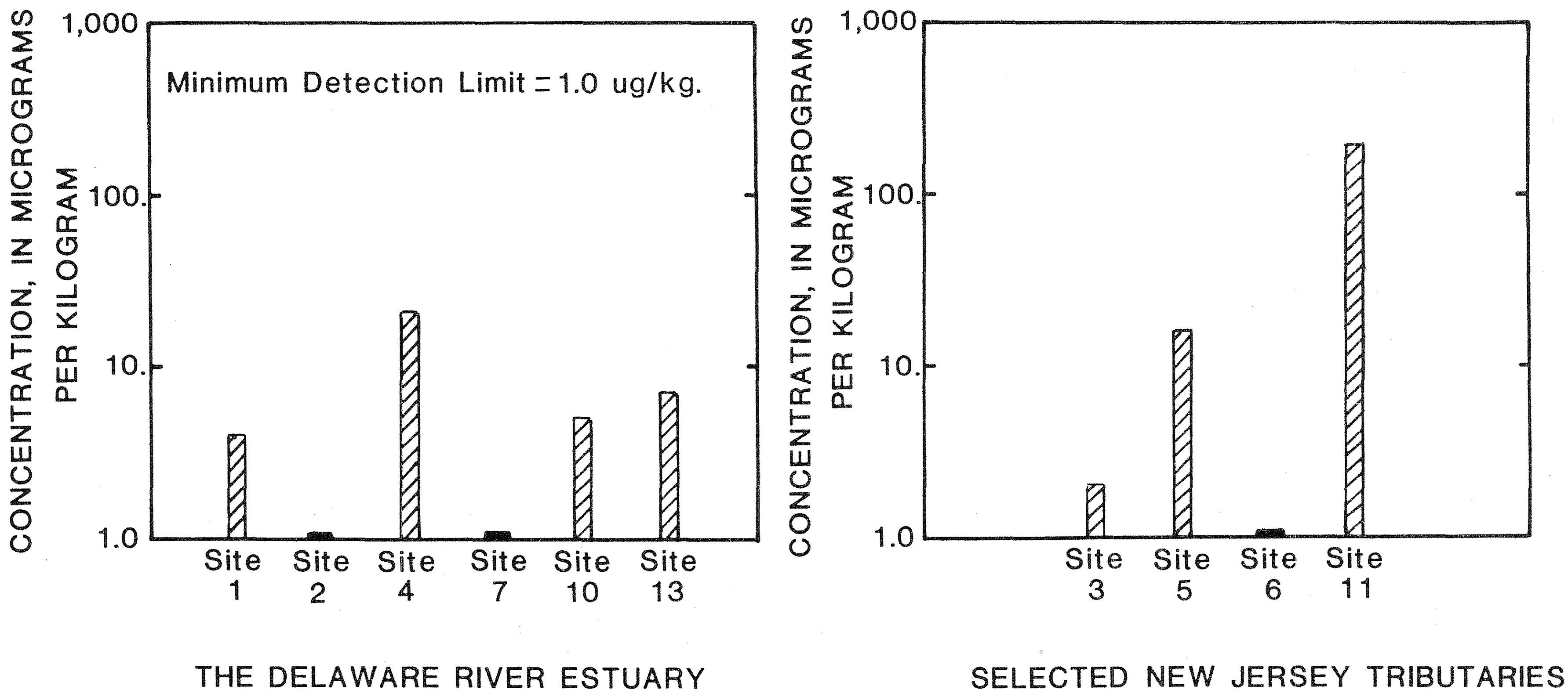


Figure 5.--Concentration of chlordane in the surficial bed material of selected sites.

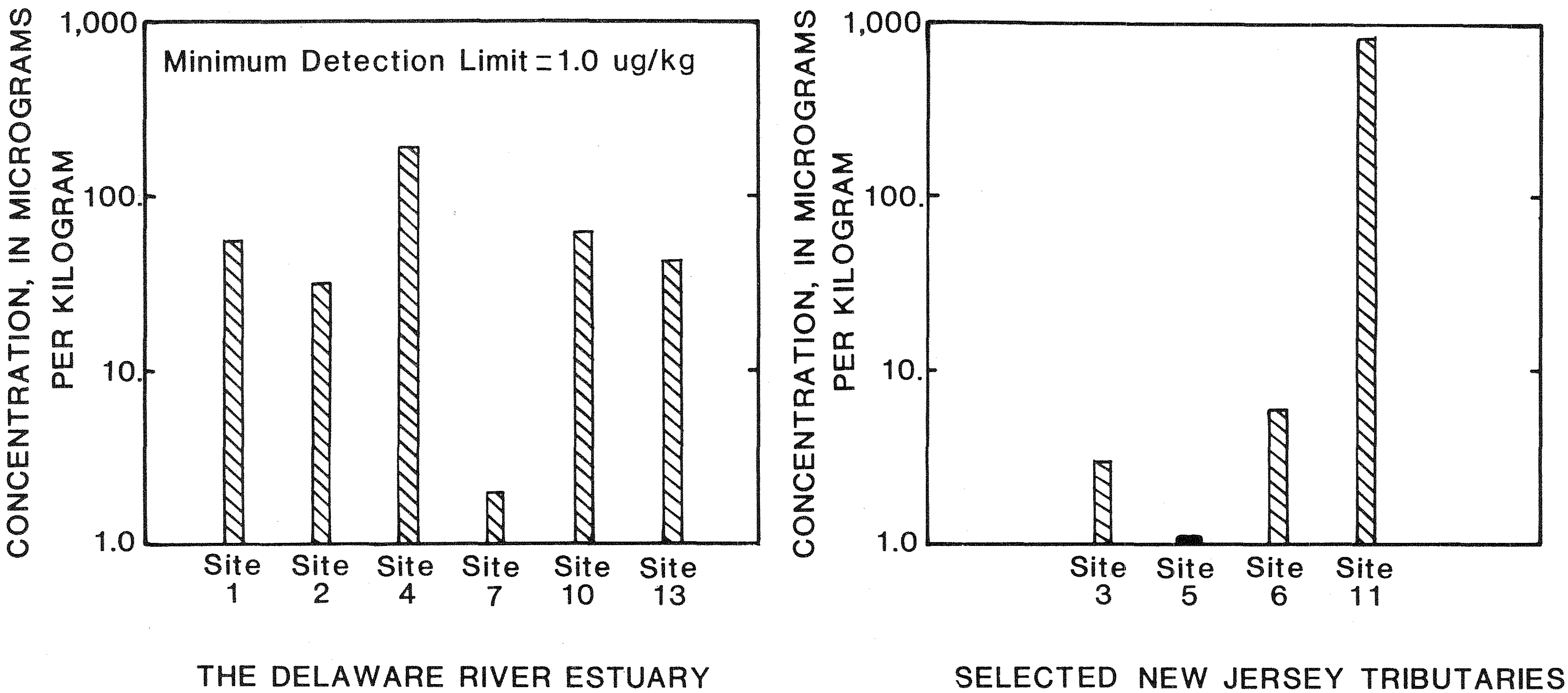


Figure 6--Concentration of PCB's in the surficial bed material of selected sites.

At the Raccoon Creek site, an additional bed material sample was analyzed for the 46 base/neutral extractable organic compounds shown in table 5. The results in table 10 show that, of the 15 constituents identified at trace or greater quantities, nine were polynuclear aromatic hydrocarbons, three were phthalate esters, and three were monocyclic chlorinated aromatics. Oil, grease, and methylbenzene were also found in this sample.

DISCUSSION

In an industrial or agricultural watershed, the potential exists for the transport of toxic substances into the water receiving surface runoff from point and nonpoint sources. Suspended sediments often act as vehicles for the transport of insoluble constituents that eventually accumulate in the surficial bed material of receiving streams (Feltz, 1980). It is not known how rapidly these accumulated constituents may leach into the surface water or migrate with the water recharging nearby aquifers. Certain insoluble organic compounds, such as DDT, are known to bioaccumulate in the tissues of certain aquatic organisms living in contaminated environments (McEwen and Stephenson, 1979).

This report presents a reconnaissance of some characteristic contaminants in the water and sediments of the Delaware River estuary region. Regionally quantifying these contaminants and assessing their impact on the water of the estuary and nearby aquifers will require more intensive study. Marked differences in constituent concentrations exist in the data collected by the U.S. Geological Survey in 1979 (table 11) and the results of this study. Such differences underscore the difficulty in reporting absolute concentrations of contaminants in surficial bed material. As indicated in table 8 by the two analyses of insecticides and PCB's at Raccoon Creek, it seems difficult to select a truly representative cross section capable of producing repeatable results for a single station.

The two cross sections selected for bed material analysis at Raccoon Creek were located within 200 feet of each other. Although the same sampling procedures were employed for each sample, the morphology of the bed at each location was very different. The surficial bed material collected in May 1980 contained more siltaceous material; whereas that collected in January 1981 contained a higher percentage of coarse to very coarse sand and gravel. A partly frozen streambed in January made removal of fine material difficult. The cross section selected in May 1980 was wider than the one selected in January 1981. This allowed for the distribution of the net discharge over a wider cross-sectional area, accounting for lower stream velocities in the wider section. Lower velocities commonly inhibit streambed scour and favor the deposition of finer particles.

Stainken (1979) was able to show that extractable hydrocarbons and percentage of volatile materials increased as the silt-clay content of Raritan Bay sediments increased. Goerlitz

Table 10.--Results of a base/neutral extractable organic compound analysis of the surficial bed material at Raccoon Creek at Bridgeport, N.J., January 8, 1981.

Compound name	Compound type	Concentration, in micrograms per kilogram
1,3-Dichlorobenzene	Monocyclic chlorinated aromatic	Trace[1]
1,2-Dichlorobenzene	--do--	--do--
1,2,4-Trichlorobenzene	--do--	--do--
Napthalene	Polynuclear aromatic hydrocarbon	--do--
2-Chloronapthalene	--do--	--do--
Acenaphthene	--do--	--do--
Dimethyl phthalate	Phthalate ester	--do--
Fluorene	Polynuclear aromatic hydrocarbon	--do--
Diethyl phthalate	Phthalate ester	--do--
Phenanthrene [not dif-	Polynuclear aromatic hydrocarbon	2.6
Anthracene ferentiated]	--do--	
Dibutyl phthalate	Phthalate ester	4.5
Fluoranthene	Polynuclear aromatic hydrocarbon	Trace[1]
Pyrene	--do--	--do--
Chrysene	--do--	Du[2]

[1] Trace, less than or equal to 2.0 µg/kg.
[2] Du, Interference from hydrocarbon contamination. Sample contains large unspecified amounts of oil, grease, and methylbenzene.

Table 11.--Results of a previous investigation of the surficial bed material in the Delaware River estuary, April 28, 1979.

Source: U.S. Geological Survey, 1980

[Results in micrograms per kilogram]

Site identification No.	Station name	Endosulfan, total	PCN, total	Aldrin, total	Lindane total	Chlordane, total	DDD, total	DDE, total	DDT, total	Dieldrin, total	Perthane, total	Endrin, total	Toxaphene, total	Heptachlor, total	Heptachlor Epoxide total	PCB, total	Mirex, total
01464575	Delaware R at PA Tpk Bdg at Edgely, Pa.	<0.1	<1	<0.1	<0.1	31	28	39	3.0	<0.1	12	<0.1	<1	<0.1	<0.1	120	<0.1
01464600	Delaware R at Bristol, Pa.	--	--	<.1	<.1	5	3.9	5.2	.5	.2	3	<.1	<1	<.1	<.1	5	--
01467060	Delaware R at Palmyra, N.J.	<.1	<1	<.1	<.1	5	510	160	<.1	.4	380	<.1	<1	<.1	<.1	33	<.1
01467200	Delaware R at Benjamin Franklin Br., at Phila., Pa.	--	--	<.1	<.1	6	10	30	<.1	3.8	26	<.1	<1	<.1	<.1	380	--
01467322	Delaware R at Walt Whitman Br., at Phila., Pa.	<.1	<1	<.1	<.1	89	31	410	7.2	6.4	<.1	<.1	<1	<.1	<.1	410	<.1
01477050	Delaware R at Chester, Pa.	--	--	<.1	<.1	90	31	130	120	2.0	<.1	<.1	<1	<.1	<.1	100	--
01482100	Delaware R at DMB, at Wilmington, Del.	--	--	<.1	<.1	27	15	35	3.0	1.2	<.1	<.1	<1	<.1	<.1	31	--

and Law (1974), however, demonstrated that the abundance of fine particles in various bed material types is not always related to higher concentrations of chlorinated hydrocarbons. Differences in contaminant concentration over time at the same site could also reflect movement of sediments in response to hydrologic events.

Table 12 lists the most recent EPA water quality limiting values and environmental profiles for selected constituents. The constituents listed were found in either the water or bed material of the study area. Since the limiting values shown have been established for water only, comparisons of actual bed material concentrations to these limiting values cannot be made.

Environmental factors influence the rate and magnitude of bed material contaminant migration. These factors include temperature, the extent of bed disturbance from dredging, surface-water velocities, channel geometry, the extent of ground water-surface water interaction, and tidal influences. Physical and chemical factors that affect bed contaminant migration include constituent solubilities, the presence of metabolizing flora or fauna, and the rate and extent of chemical decomposition, including the persistence of any decomposition byproducts.

Despite the poor quantitative comparability between data collected in 1979 and data collected for this report, several qualitative trends are apparent. Throughout both studies, relatively soluble organophosphorous insecticides were virtually absent from the bed material. Chlordane and dieldrin were prevalent in the estuarine bed material in 1979 and 1980. In 1979, perthane was found throughout the bed material of the upper estuary, whereas, in 1980, perthane was detected at the Delaware River at Palmyra.

Concentrations of DDE and DDD in bed material were usually higher than that of DDT in both studies. This relationship would suggest that most of the DDT in the estuary has undergone metabolic changes and persists in the form of breakdown components (Barthel and others, 1966). The use of DDT has been banned in all but the most extreme situations since January 1, 1973, yet DDT and its metabolites still persist in the surficial bed material.

PCB's were prevalent in the bed material samples collected for this study and in 1979. A voluntary ban on the sale of PCB's for open application, such as plasticizers and adhesives, has been in effect since 1970, and the only U.S. manufacturer ceased production in 1977 (National Academy of Sciences, 1979). The presence of PCB's in the 1979 and 1980 samples attests to the known persistence of PCB's in the aquatic environment (Sax, 1974, p. 661).

The significance of the polynuclear aromatic hydrocarbon (PAH) distribution in the bed material of the Raccoon Creek cannot be determined based on one sampling. If more data were available,

Table 12.--Chemical properties and environmental significance of selected constituents.

Name	Formula	EPA designated limiting value (in H_2O)	Selection criteria	Remarks
				Selected metals
Cadmium	Cd	[1] [2] 4.5 µg/L 59.0 µg/L 10.0 µg/L	A B C D E	Occurs naturally as greenockite (CdS)ore*[2]. Cd has multiple industrial uses including electroplating, paint pigments, and in batteries. LD_{50}(oral) ranges from 14 mg/kg for Cd lactate to 660 mg/kg for Cd succinate.*[3]
Iron	Fe	300 µg/L 1,000 µg/L	G B	Hematite (red and brown) is the most common iron ore.*[1] The principal objection to Fe in domestic water supplies is aesthetic.
Manganese	Mn	50 µg/L	G	Important ores of Mn are pyrolusite and manganite.*[2] Mn decomposes in water and is used in the manufacture of steel and various alloys.*[5]
				Selected organic compounds
Benzene	C_6H_6	5,300 µg/L 5,100 µg/L 0.00 µg/L 6.6 µg/L	B D E F	A clear, colorless, volatile liquid with an aromatic odor. Benzene is an important fractional component of fuel oil.*[6] Benzene is used as a constituent of motor fuels, and as an intermediate in the manufacture of styrene, cyclohexane, detergents, and pesticides.*[7] Benzene is a recognized carcinogen and a cumulative toxin. It is slightly soluble in H_2O (0.8 PPM).*[7]
Chlordane	$C_{10}H_6Cl_8$	0.0043 µg/L 2.4 µg/L 0.0040 µg/L 0.09 µg/L 0.00 µg/L 0.0046 µg/L	A B C D E F	A polycyclic chlorinated hydrocarbon insecticide. Chlordane has been used for over 30 years in termite control *[10]. Acute LD_{50} (oral) is 457-590 mg/kg.*[5] Its solubility in water is low (9 PPB).*[7]

[1] $e^{[1.05 \ln(\text{hardness}) - 8.53]}$ µg/L

[2] $e^{[1.05 \ln(\text{hardness}) - 3.73]}$ µg/L

Table 12.--Chemical properties and environmental significance of selected constituents--Continued.

Name	Formula	EPA designated limiting value (in H_2O)	Selection criteria	Remarks
		Selected organic compounds--Continued		
DDT (Dichloro-diphenyl trichloro-ethane)	$C_{14}H_9Cl_5$	0.0010 µg/L 1.1 µg/L 0.13 µg/L 0.00 µg/L 0.00024 µg/L	A&C B D E F	DDT, and its metabolites DDE ($C_{14}H_8Cl_4$) and DDD ($C_{14}H_{10}Cl_4$) are broad spectrum chlorinated hydrocarbon insecticides. DDD (also known as TDE) is also formulated independently as an insecticide. DDT-T (particularly DDE) is accumulated in body fat.[*3]+[*7] Oral LD_{50} (male rats) for DDT = 113 mg/kg; for DDE = 800 mg/kg; for DDD = 3,400 mg/kg.[*3] DDT and DDE are slightly soluble in H_2O (1.3 PPB). DDD has separate limiting values for the protection of freshwater/saltwater aquatic life of 0.6/3.6 µg/L based on acute toxicity.[*1]
Dieldrin	$C_{12}H_8Cl_6O$	0.0019 µg/L 2.5 µg/L 0.71 µg/L 0.00 µg/L 0.00071 µg/L	A&C B D E F	A cyclodiene chlorinated hydrocarbon insecticide. Acute oral LD_{50} = 46 mg/kg.[*5]+[*7] Dieldin has a very low vapor pressure, and is slightly soluble in water (186 µg/L at 25°C).[*1] Dieldrin is stored in animal fat and is thus subject to biomagnification in the food cycle. Manufacture of dieldrin in the U.S. was suspended in 1974.
Endo-sulfan	$C_9H_6Cl_6O_3S$	0.056 µg/L 0.22 µg/L 0.0087 µg/L 0.034 µg/L 74.0 µg/L	A B C D E	A cyclodiene chlorinated hydrocarbon insecticide. Acute oral LD_{50} is 100 mg/kg.[*3]+[*5] Endosulfan appears to be particularly damaging to the central nervous system.[*1] It is considered insoluble in water.[*3]
Heptachlor	$C_{10}H_5Cl_7$	0.0038 µg/L 0.52 µg/L 0.0036 µg/L 0.053 µg/L 0.00 µg/L 0.00278 µg/L	A B C D E F	Heptachlor and its principal metabolite, heptachlor epoxide ($C_{10}H_7OCl_7$) are polycyclic chlorinated hydrocarbon insecticides. Acute oral LD_{50} for heptachlor is 90 mg/kg,[*5] and for the epoxide it is 46.5 mg/kg.[*7] Heptachlor is soluble in H_2O at about 56 PPB,[*7] while the epoxide is soluble in water at about 350 PPB.

Table 12.--Chemical properties and environmental significance of selected constituents--Continued.

Name	Formula	EPA designated limiting value (in H_2O)	Selection criteria	Remarks
		Selected organic compounds--Continued		
PCB's (Polychlorinated biphenyls)	$C_{12}H_{10-x}Cl_x$	0.014 µg/L 0.030 µg/L 0.00 µg/L 0.00079 µg/L	A C E F	PCB's (Arochlors) are joined by the chlorination of diphenyl rings (C_{12}). Although 209 possible substitutions of chlorine for hydrogen are possible (including all isomers), the industrially significant products are those containing 21, 42, 48, 54, and 60 percent chlorine by weight.*[3] Technical PCB can also include such contaminants as chlorinated napthalenes and chlorinated dibenzofurans. PCB's were introduced over 45 years ago and are known to be almost chemically inert.*[1] Their principal vehicle for movement in the environment is believed to be water,*[3] and strong evidence exists for their tendency to accumulate in food chains.*[1] They are generally low in acute toxicity (LD_{50} oral(mice) = 2,000 mg/kg), however they are considered to be quite toxic after chronic long term exposure.*[3] PCB's are useful as electrical insulating mediums and as a heat-transfer fluid. The solubilities of PCB's in water vary from 2 to 250 PPB depending on the specific Arochlor.*[3]+*[7]
PAH's (Polynuclear aromatic hydrocarbons)	Compounds containing multiple unsaturated carbon rings	0.00 µg/L 0.028 µg/L	E F	PAH's can be formed in any hydrocarbon combustion or decomposition process from a multitude of anthropogenic and natural sources, including forest fires and oil spills. Many PAH's are known to have mutagenic and carcinogenic effects.*[9]
PCE (Tetrachloroethylene)	$Cl_2C{:}CCl_2$	840 µg/L 5,280 µg/L 450 µg/L 10,200 µg/L 0.00 µg/L 8.0 µg/L	A B C D E F	PCE is commonly used as a dry cleaning and industrial solvent, as a heat transfer medium and in the manufacture of fluorocarbons. PCE does not appear to be a cumulative toxin.*[7] PCE is considered insoluble in water.*[8]

Table 12.--Chemical properties and environmental significance of selected constituents--Continued.

Name	Formula	EPA designated limiting value (in H_2O)	Selection criteria	Remarks
		Selected organic compounds--Continued		
Toluene	$C_6H_5CH_3$	17,500 µg/L 5,000 µg/L 6,300 µg/L 14.3 mg/L	B C D E	Toluene is a colorless liquid that is an important fractional component of fuel oil. It is formed in petroleum refining and coal for distillation.*[7] Toluene is considered insoluble in water.*[7]
TCE Trichloroethylene	ClCH: CCl_2	45,000 µg/L 2,000 µg/L 0.00 µg/L 27.0 µg/L	B D E F	TCE is a heavy colorless liquid that is principally used as a degreasing solvent. It also is used to decaffeinate coffee and as a dry cleaning agent.*[1] Its acute oral LD_{50} is 4,920 mg/kg.*[7] TCE is considered slightly soluble in water.*[2]

NOTES: All of table twelve's limiting values are referenced to Sittig (1981). Sittig compiled these values from the U.S. Environmental Protection Agency Ambient Water Quality Criteria Series (1980), and the Health and Environmental Effects Profiles Series (1980).

LD_{50} (lethal dose, 50 percent). The dose of a substance that is fatal to 50 percent of exposed organisms under test conditions within a specified period of time. A substance having an LD_{50} of less than 50 mg per kg of body weight is regarded by toxicologists as highly toxic.

REFERENCES FOR REMARKS COLUMN:
*[1] = Sittig (1981);
*[2] = Hawley (1981);
*[3] = Sax (1974);
*[4] = U.S. Environmental Protection Agency (1976);
*[5] = Windholz and others (1976);
*[6] = Zurcher and Thuer (1978);
*[7] = National Research Council (1977);
*[8] = Weast and Astle (1979);
*[9] = Josephson (1981);
*[10] = Meister Publishing Company (1981).

SELECTION CRITERIA:
A = to protect freshwater aquatic life - 24 hour average value
B = to protect freshwater aquatic life - value not to be exceeded
C = to protect saltwater aquatic life - 24 hour average value
D = to protect saltwater aquatic life - value not to be exceeded
E = preferred limit to protect human health
F = this concentration poses an additional lifetime cancer risk of 1 in 100,000
G = maximum level recommended for domestic water supply

the techniques outlined by Lake and others (1979) might be helpful in determining the origins of the PAH's detected.

The volatile organic composition of the water samples varied significantly between sites and between samplings. Trichloroethylene and tetrachloroethylene were among the predominant halogenated organic compounds found in this study, and in a similar surface-water study by EPA in Pennsylvania and Ohio (Dreisch and others, 1980).

Hydrocarbons in the estuary can result from many point and nonpoint sources, including atmospheric deposition. Benzene and toluene are potential decomposition byproducts of petroleum products (Zurcher and Thuer, 1978). Cyclohexane also exists as a component part of crude petroleum (Hawley, 1981, p. 297). It seems that many volatile organic compounds exist in the Delaware River estuary with instantaneous sampling conditions determining what will be found in a sample at any given time, thus making a description of spatial and time distribution impossible at present.

SUMMARY AND CONCLUSIONS

This report presents a reconnaissance of organic and inorganic contaminants in the water and bed material of the Delaware River estuary region. The water and surficial bed material of six Delaware River estuary sites and four tidal tributaries in New Jersey were sampled from May 1980 to January 1981. Most water samples were collected during the outgoing (receding) segment of the tidal cycle. The water at three additional tributaries in New Jersey were sampled for organic and inorganic constituents.

The inorganic quality of the water is characterized by increased chloride and sulfate levels in the lower part of the estuary. Sodium was the predominate cation in the lower estuary, whereas calcium predominated upstream from Philadelphia. Moderate amounts of manganese were recorded throughout the region.

No single volatile organic compound persisted in the water of the estuary during the study. Benzene, toluene, 1,1-dichloropropane, tetrachloroethylene, and trichloroethylene were found at various times and locations at concentrations ranging from 1 to 12 µg/L. Undifferentiated hydrocarbons, including cyclohexane, were found in the Delaware River estuary at concentrations ranging from 20 to 50 µg/L.

No measureable amounts of acid extractable or base/neutral extractable organic compounds were found in the water at any site. Trace quantities of 15 base/neutral extractable organic substances, in addition to toluene and oil and grease, were found in the surficial bed material at Raccoon Creek. These compounds included nine polynuclear aromatics, three phthalate esters, and three chlorinated benzenes.

The surficial bed material of the region was generally low in trace metals, except at Raccoon Creek at Bridgeport and Delaware River at Palmyra. The bed material of Raccoon Creek in May 1980 contained high concentrations of cadmium (20 μg/g), chromium (190 μg/g), cobalt (50 μg/g), copper (230 μg/g), lead (590 μg/g), and zinc (2,100 μg/g). The Delaware River at Palmyra had high concentrations of copper (70 μg/g), lead (150 μg/g), and zinc (530 μg/g) in the bed material.

At most of the locations, the surficial bed material contained measurable concentrations of DDD, DDE, PCB, DDT, and chlordane. Only the bed material at Delaware River at Palmyra contained perthane (510 μg/kg). The only organophosphorous insecticide detected in the bed material of the region was diazinon (1.6 μg/kg) at Raccoon Creek at Bridgeport.

SUGGESTIONS FOR FURTHER STUDY

Factors not quantified in this study, but considered necessary for a comprehensive assessment of water and bed material contamination in the estuary include: (1) regional base/neutral extractable organic analyses of the surficial bed material to assist in identifying sources of industrial organic waste; (2) extensive bed material analyses for trace metals and hydrophobic organic substances, including organochlorine pesticides and PCB's, particularly along the tidal Raccoon Creek (including core analyses of the bed at selected locations for possible contaminants buried beneath surficial sediments); (3) further assessment of the occurrence and distribution of volatile organic compounds, including a study of their fate and significance in surface-water systems; (4) analysis of the mobilization of low-solubility metals and organic substances from the bed material into nearby ground and surface water; and (5) evaluation of current and proposed deposition sites for channel dredged spoils, to determine the potential for leachate contamination into hydraulically-connected aquifers and streams.

Accumulation in the bottom sediments may afford the only opportunity for detection of insoluble substances in many surface-water systems, apart from water analyses performed at or near known sources of contamination. Analyses for hydrophyllic substances, such as acid extractable organic compounds, should be restricted to water samples. These substances have high aqueous solubilities, making their long term retention in sediments unlikely (Lewis Lowe, oral communication, 1981).

SELECTED REFERENCES

Barksdale, H. C., Greenman, D. W., Lang, S. M., Hilton, G. S., and Outlaw, D. E., 1958, Ground-water resources in the tri-state region adjacent to the lower Delaware River: New Jersey Department of Conservation and Economic Development Special Report 13, 190 p.

Barthel, W. F., Parsons, D. A., McDowell, L. L., and Grissinger, E. H., 1966, Surface hydrology and pesticides: Soil Science Society of America, Inc., American Soil Association Special Publication no. 8, 150 p.

Beetem, W. A., Friedman, L. C., Perryman, G. R., and Watterson, C. A. (eds.), 1980, 1981 Water Quality Laboratory Services Catalog: U.S. Geological Survey Open-File Report 80-1279, p. 2.6.1 - 2.6.10.

Cohen, Bernard, and McCarthy, L. T., Jr., 1962, Salinity of the Delaware Estuary: U.S. Geological Survey Water-Supply Paper 1586-B, 47 p.

Delaware River Basin Commission, 1975, Industrial Discharge Inventory: West Trenton, N.J., 5 p.

____________ 1981, The Delaware River basin comprehensive (Level B) study: West Trenton, N.J., 140 p.

Delaware Valley Regional Planning Commission, 1977, Ground water quality problems: Delaware Valley Regional Planning Commission 208 Study, 39 p.

____________ 1979, Year 2000 land use and open space plan: Philadelphia, Pa. 104 p.

Dreisch, F. A., Gower, Marilyn, and Manson, T. O., 1980, Survey of the Huntington and Philadelphia river water supplies for purgeable organic contaminants: U.S. Environmental Protection Agency Region III, Report No. EPA-903/9-81-003, 14 p.

Feltz, H. R., 1980, Significance of bottom material data in evaluating water quality, in Baker, R. A., ed., Contaminants and Sediments, Volume 1: Ann Arbor Science Publishers, Inc., p. 271-287.

Garbarino, J. R., and Taylor, H. E., 1979, An inductive-coupled plasma atomic emission spectrometric method for routine water quality testing: Applied Spectroscopy, v. 33, no. 3, p. 220-226.

Goerlitz, D. F., and Brown, Eugene, 1972, Methods for analysis of organic substances in water: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A3, 40 p.

Goerlitz, D. F., and Law, L. M., 1974, Distribution of chlorinated hydrocarbons in stream-bottom material: U.S. Geological Survey Journal of Research, v. 2, no. 5, p. 541-543.

Greenman, D. W., Rima, D. R., Lockwood, W. N., and Meisler, Harold, 1961, Ground-water resources of the Coastal Plain of southeastern Pennsylvania: Pennsylvania Geological Survey Bulletin W-13, 375 p.

Guy, H. P., and Norman, V. W., 1970, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter C2, 59 p.

Harleman, D. R. F., and Lee, C. H., 1969, The computation of tides and currents in estuaries and canals: Committee of Tidal Hydrology, U.S. Army Corps of Engineers, Technical Bulletin No. 16, 264 p.

Hawley, G. G., 1981, The condensed chemical dictionary: New York, Van Nostrand Reinhold Co., 1135 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water, [2d ed.]: U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Josephson, Julian, 1981, Polynuclear aromatic hydrocarbons: Environmental Science and Technology, v. 15, no. 1, p. 20-22.

Keighton, W. B., 1966, Fresh-water discharge-salinity relations in the tidal Delaware River: U.S. Geological Survey Water-Supply Paper 1586-G, 16 p.

Keith, L. H., and Telliard, W. A., 1979, Priority Pollutants I - a perspective view: Environmental Science and Technology, v. 13, no. 4, p. 416-423.

Lake, J. L., Norwood, Curtis, Dimock, Crandall, and Bowen, Robert, 1979, Origins of polycyclic aromatic hydrocarbons in estuarine sediments: Geochimica et Cosmochimica, v. 43, p. 1847-1854.

Luzier, J. E., 1980, Digital-simulation and projection of head changes in the Potomac-Raritan-Magothy aquifer system, Coastal Plain, New Jersey: U.S. Geological Survey Water-Resources Investigations 80-11, 72 p.

Mansue, L. J., and Commings, A. B., 1974, Sediment transport by streams draining into the Delaware Estuary: U.S. Geological Survey Water-Supply Paper 1532-H, 18 p.

McCartney, David, and Beamer, N. H., 1964, The complexity of water quality in the Delaware Estuary: American Institute of Chemical Engineers preprint 18b, 23 p.

McEwen, F. L., and Stephenson, G. R., 1979, The use and significance of pesticides in the environment: New York, John Wiley and Sons, p. 453-465.

Meister Publishing Company, 1981, Farm Chemicals Handbook: Willoughby, Oh., 655 p.

Miller, E. G., 1962, Observations of tidal flow in the Delaware River: U.S. Geological Survey Water-Supply Paper 1586-C, 26 p.

National Academy of Sciences, 1979, Polychlorinated biphenyls: Committee on the Assessment of Polychlorinated Biphenyls in the Environment, Environmental Studies Board, Commission on Natural Resources, Washington, D.C., National Academy of Sciences, 182 p.

National Research Council, 1977, Drinking water and health: National Academy of Sciences, 939 p.

Owens, J. P., and Minard, J. P., 1979, Upper Cenozoic sediments of the lower Delaware Valley and the northern Delaware Peninsula, New Jersey, Pennsylvania, Delaware, and Maryland: U.S. Geological Survey Professional Paper 1067-D, 47 p.

Parker, G. G., Hely, A. G., Keighton, W. B., Olmsted, F. H., and others, 1964, Water resources of the Delaware River basin: U.S. Geological Survey Professional Paper 381, 200 p.

Powell, S. T., Consulting Engineers, Baltimore, Maryland, and Legette and Brashears, Consulting Ground-Water Geologists, New York, 1954, Report on the effect of ship channel enlargement above Philadelphia: Report prepared for The Committee for Study of the Delaware River, Appendix A2-1.

Rhodehamel, E. C., 1970, A hydrologic analysis of the New Jersey Pine Barrens region: New Jersey Department of Environmental Protection, Division of Water Resources, Water Resources Circular 22, 35 p.

Sax, N. I. (ed.), 1974, Industrial Pollution: New York, Van Nostrand Reinhold Co., 702 p.

Scheier, Arthur, and Kiry, Paul, 1973, A discussion of the effects of certain potential toxicants on fish and shellfish in the upper Delaware Estuary: The Philadelphia Academy of Natural Sciences, 54 p.

Sheldon, L. S., and Hites, R. A., 1978, Organic Compounds in the Delaware River: Environmental Science and Technology, v. 12, no. 10, p. 1188-1194.

__________ 1979, Sources and movement of organic chemicals in the Delaware River: Environmental Science and Technology, v. 13, no. 5, p. 574-579.

Sittig, Marshall, 1981, Handbook of toxic and hazardous chemicals: Noyes Publications, 729 p.

Skougstad, N. W., Fishman, M. J., Friedman, L. C., Erdmann, D. E., and Duncan, S. S., 1979, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A1, 626 p.

Stainken, Dennis, 1979, Occurrence of extractable hydrocarbons in sediments from Raritan Bay, New Jersey: Bulletin of the New Jersey Academy of Science, v. 24, no. 1, p. 6-11.

U.S. Environmental Protection Agency, 1977, Quality Criteria for Water: U.S. Government Printing Office, Washington, D.C., 256 p.

__________ 1979a, EPA Method 624-Purgeables: Federal Register, v. 44, no. 233, p. 69532-69539.

__________ 1979b, EPA Method 625-Base/neutrals, Acids, and Pesticides: Federal Register, v. 44, no. 233, p. 69540-69552.

U.S. Geological Survey, 1952, Index of water resources records in the Delaware River basin to September 30, 1951: U.S. Geological Survey Circular 190, 19 p.

__________ 1980, Water Resouces Data for Pennsylvania, Volume 1, Delaware River basin: U.S. Geological Survey Water-Data Report, PA-79-1, 277 p.

U.S. National Oceanic and Atmospheric Administration, 1973, Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-1970 (New Jersey): National Climatic Center, Climatography of the United States No. 81, Asheville, North Carolina.

Vowinkel, E. F., and Foster, W. K., 1981, Hydrogeologic conditions in the Coastal Plain of New Jersey: U.S. Geological Survey Open-File Report 81-405, 39 p.

Weast, R. C., and Astle, M. J. (eds.), 1979, Handbook of chemistry and physics: Boca Raton, Fla., Chemical Rubber Co., 2447 p.

Weil, C. B., 1977, Sediments, structural framework, and evolution of Delaware Bay, a transgressive estuarine delta: The Delaware Sea Grant College Program, College of Marine Studies, University of Delaware, 199 p.

Willard, Bradford, 1962, Pennsylvania geology summarized: Pennsylvania Department of Environmental Resources Educational Series No. 4, 17 p.

Windholz, Martha, Budavari, Susan, Stroumtsos, L. Y., and Fertig, M. N. (eds.), 1976, The Merck Index, Ninth Edition: Rahway, N.J., Merck and Company, Inc., 1937 p.

Zurcher, Fritz, and Thuer, Markus, 1978, Rapid weathering processes of fuel oil in natural waters: Analyses and interpretations: Environmental Science and Technology, v. 12, no. 7, p. 838-843.

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