CHEMICAL QUALITY OF THE SAW MILL RIVER, WESTCHESTER COUNTY, NEW YORK, 1981-83

By Robert J. Rogers

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CONTENTS

Page

Abstract 1
Introduction 2
    Purpose and scope 4
    Acknowledgments 4
Basin description. 4
    Physiography and geology. 4
    Climate 5
    Streamflow. 5
    River quality 6
    Land use. 7
Data collection. 7
    Sampling media and sample collection. 7
        Bottom sediments 7
        River water. 10
        Soils. 10
        Ceramic tiles. 11
    Sample preparation and analyses 11
        Sample preparation 11
        Chemical analyses. 12
        Grain-size analyses. 13
Chemical quality of Saw Mill River 15
    Nutrients 15
        River water. 15
        Bottom sediments 15
    Heavy metals. 16
        River water. 16
        Bottom sediments 16
        Soils. 23
        Ceramic tiles. 25
    Organic compounds 28
        River water. 28
        Bottom sediments 29
Relation of river quality to urbanization. 35
Summary. 37
References 40

ILLUSTRATIONS

Figure 1.--Map showing location of sampling sites in the Saw Mill River basin 3

2.--Elevation profile of the Saw Mill River 4

3.--Hydrograph showing monthly streamflow of the Saw Mill River at Yonkers. 6

ILLUSTRATIONS (continued)

Page

Figure 4.--Graph showing relation of heavy-metal concentration to sediment grain size at site 320, near upper end of basin, and site 503, near lower end of basin 18

5.--Plots showing heavy-metal concentrations in 1,000- to 2,000-μm bottom sediment in the Saw Mill River
A. Copper, lead, and zinc. B. Iron and manganese 21

6.--Graph showing concentrations of heavy metals deposited on ceramic tiles emplaced in the Saw Mill River 27

7.--Plots showing chlorinated hydrocarbon concentrations in bottom sediments in the Saw Mill River.
A. Dieldrin and DDD + DDE + DDT. B. Chlordane and PCB. . . . 29

TABLES

Table 1.--Location of the 20 sampling sites on the Saw Mill River and tributaries 9

2.--Acid- and base/neutral-extractable organic compounds for which water and bottom-sediment samples were analyzed 13

3.--Principal volatile organic compounds for which water samples were analyzed 14

4.--Organochlorine and organophosphorous compounds for which water and bottom-sediment samples were analyzed 14

5.--Heavy-metal concentrations is size fraction of bottom sediments from the Saw Mill River, 1981 17

6.--Dry-weight percentage of sediment size fractions in river-bottom sediments from Saw Mill River and tributaries, 1981. . 19

7.--Heavy-metal concentrations in 1,000- to 2,000-μm bottom sediment from the Saw Mill River and tributaries, 1981-82 . . 20

8.--Correlation coefficients of heavy metals in upstream and downstream bottom sediments from the Saw Mill River and tributaries, 1981-82. 23

9.--Heavy-metal concentrations in soils from the Saw Mill River basin, 1981 24

10.--Heavy-metal concentrations on ceramic tiles emplaced on bottom of the Saw Mill River 26

TABLES (continued)

Page

Table 11.--Concentrations of volatile organic compounds in the Saw Mill River, 1981-82 28

12.--Concentrations of organochlorine compounds in bottom sediments from the Saw Mill River, 1981 30

13.--Concentrations of organochlorine compounds in bottom sediments from the Saw Mill River, 1976 31

14.--Concentrations of acid- and base/neutral-extractable compounds in bottom sediments from the Saw Mill River, 1981-82 . 32

15.--Uses of selected heavy metals 36

16.--Concentrations of nitrogen, phosphorus, and carbon in water from the Saw Mill River, 1981-82. 44

17.--Concentrations of nitrogen, phosphorus, and carbon in bottom sediments from the Saw Mill River, 1981-82 46

18.--Concentrations of heavy metals in waters from the Saw Mill River, 1981-82. 50

CONVERSION FACTORS AND ABBREVIATIONS

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

Multiply inch-pound unit	By	To obtain SI (metric) unit
inch (in.)	2.54	centimeter (cm)
foot (ft)	30.48	centimeter (cm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallons (gal)	0.003785	cubic meter (m^3)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
degrees Fahrenheit (°F)	1.8 x °C+32	degrees Celsius (°C)

Other Abbreviations

micrometers (µm)
milligrams per liter (mg/l)
micrograms per liter (µg/l)
micrograms per gram (µg/g)
milligrams per kilograms (mg/kg)
micrograms per kilogram (µg/kg)
nanograms per sqare centimeter (ng/cm^2)

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ABSTRACT

Concentration and distribution of contaminants in the Saw Mill River, which drains a heavily developed basin adjacent to New York City, was studied during 1981-83. River water and bottom sediments were analyzed for nutrients, heavy metals, and synthetic organic compounds. Coatings that formed on submerged ceramic tiles emplaced in the river for the study were analyzed for heavy metals. Soils near the river were also analyzed for heavy metals.

Bottom-sediment chemistry was the main focus of the study. Bottom sediments from six sites were separated into six size fractions to determine the relationship between grain size and concentrations of heavy metals and nutrients. The spatial distribution of heavy metals in bottom sediments was investigated by using 1,000- to 2,000-micrometer (μm) sediment; the distribution of organic compounds was investigated by using sediment composed of all particles less than 2,000 μm.

Among the nutrients studied, nitrite, nitrate, and un-ionized ammonia concentrations did not exceed U.S. Environmental Protection Agency (USEPA) water-quality criteria. The highest concentrations of dissolved orthophosphate (0.04 to 0.10 milligrams per liter) were observed in the lower 8 miles of the river. Nitrogen, phosphorus, and organic carbon concentrations were typically higher in 1,000-to 2,000-μm bottom sediments than in 250- to 1,000-μm sediment and were highest in the fraction less than 250 μm.

The only heavy metal to regularly exceed USEPA criteria was dissolved manganese. The highest concentrations of arsenic, cadmium, copper, lead, and zinc were in water from the lower 4 river miles. In bottom sediments, heavy-metals concentrations were higher in 1,000- to 2,000-μm sediment than in 500-to 1,000-μm sediment and highest in the fraction less than 250 μm. Sediments in the 1,000- to 2,000-μm fraction from the lower 3 river miles contained significantly greater amounts of copper, lead, and zinc than sediments upstream, and concentrations of these metals were also highest in riverbank soils below river mile 3.0. The most abundant metal deposited on the ceramic tiles was manganese. Concentrations of all metals investigated--cadmium, cobalt, copper, iron, lead, manganese, nickel, and zinc--were highest on tiles from below river mile 3.0.

Few organic compounds were detected in the river water. Four volatile organic compounds were detected at concentrations of 2 to 30 micrograms per liter (μg/L). Samples from three of 11 sites contained total phenol concentrations of 1 to 4 μg/L; the rest were below detection limit. Polychlorinated biphenyls (PCB's) were detected in one water sample at a concentration of 0.1 μg/L. Chlordane, DDD, DDE, DDT, dieldrin, and PCB were found in bottom sediments throughout the basin. The six highest PCB concentrations (58 to 2,100 micrograms per kilogram) were found in the lower 6 river miles. Chlordane was the most abundant pesticide in the bottom sediments. None of the pesticides

exhibited a spatial pattern. Of the 57 acid- and base/neutral-extractable compounds on the USEPA "priority pollutant" list, 22 were detected in bottom sediments; 16 were polynuclear aromatic hydrocarbons; and 4 were phthalate esters. None of the 22 compounds was found at all sites sampled. The greatest number of organic compounds was found below river mile 2.0. Cyanide was not detected in any water or bottom-sediment sample.

The area below river mile 3.7 is the most heavily urbanized part of the basin. Concentrations of orthophosphate, heavy metals, PCB's, and polynuclear aromatic hydrocarbons increase downstream and are highest in the urbanized reach below river mile 3.7. Urban runoff, rather than recorded point sources of contaminants, is considered the major cause of the downstream deterioration in river quality.

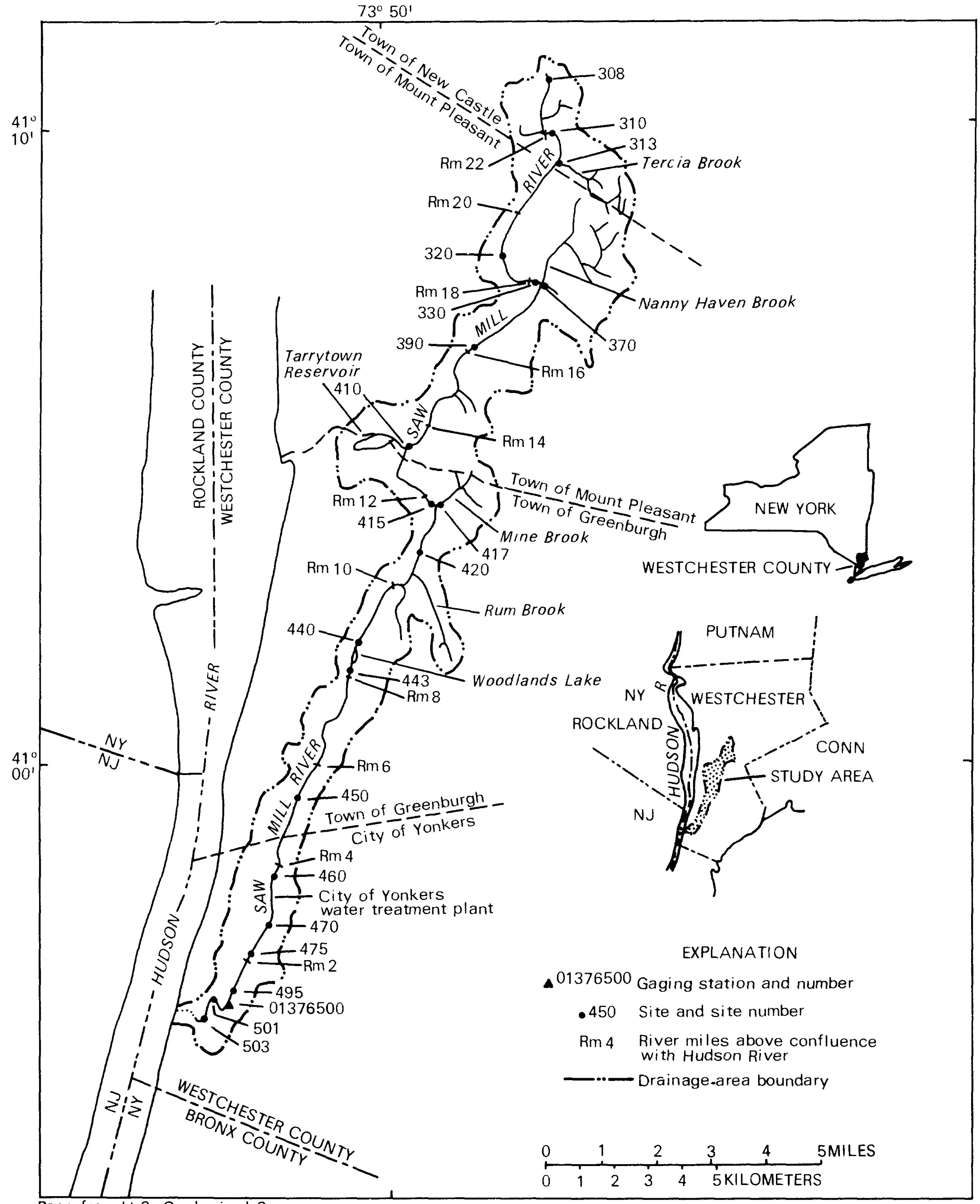
INTRODUCTION

The chemical quality of rivers is affected by virtually all types of development. Many compounds entering a river as a consequence of urban development do so from point sources and from general runoff. Potential contaminants include plant nutrients, heavy metals, and synthetic organic compounds such as pesticides. Contaminants commonly enter a river at low, subtoxic concentrations but may accumulate in the bottom sediments. If the contaminants reach critical concentrations within the sediment, they prove toxic to aquatic life and, if redissolved or suspended, may render a river unfit for use as a water supply. Thus, assessments of river quality must consider not only the quality of the water but also of the bottom sediments.

Many residents of Westchester County in southwestern New York (fig. 1) rely on the Saw Mill River drainage for part of their water supply. The lower section of the river flows through the City of Yonkers, a heavily urbanized section of the county. Results of a 1976 study by the U.S. Geological Survey (Archer and Turk, 1977) suggest that bottom sediments in the downstream (southern) section of the river are enriched in metals and organochlorine compounds.

Discharge of wastewater into the Saw Mill River is stringently controlled. No municipal waste and few recorded industrial wastes are discharged to the river. However, county officials have for many years received reports of illegal and accidental discharges into the river, especially along the lower reaches, and untreated domestic sewage occasionally enters the river as a consequence of broken pipes or other malfunctions. The Westchester County Department of Health routinely investigates all reports of spills and discharges.

The City of Yonkers maintains a water-treatment plant at about river mile 3.2 to meet part of its water needs. The plant has been closed at times because of turbid water or low-flow conditions, and in August 1982 the plant was closed because of objectionable taste and odor and remained closed as of September 1984. Other water users include the Village of Tarrytown in the Town of Greenburgh, which maintains a reservoir on a tributary (fig. 1), and several industries that use the river as a source of cooling water.



Base from U.S. Geological Survey
State base map, 1:500,000, 1974

Figure 1.--Location of sampling sites in the Saw Mill River basin.

Purpose and Scope

In October 1980, the U.S. Geological Survey, in cooperation with the Westchester County Department of Health, began a 3-year study of the chemical quality of the Saw Mill River. This report, which presents the results of that study, (1) identifies contaminants in the river and provides information on their concentration, and (2) describes the distribution of contaminants and relates the distribution to land use, urbanization, and possible sources.

The sampling program, which extended from February 1981 through February 1983, covered the entire river and several tributaries. Emphasis was placed on the quality of river-bottom sediments, which strongly sorb many contaminants from the water column. Bottom sediments were sampled at 20 sites; water samples were collected at 11 of the sites. Water and bottom-sediment samples were analyzed for heavy metals (density >6 g/cm^3), major nutrients, U.S. Environmental Protection Agency (USEPA) "priority pollutants" (Keith and Telliard, 1979), and other synthetic organic compounds, such as pesticides. Soil samples from 10 sites in the river's drainage basin were analyzed to aid in interpreting the heavy-metal chemistry of the bottom sediments.

Acknowledgments

The Westchester County Department of Health provided technical support and partial funding for this study.

BASIN DESCRIPTION

Physiography and Geology

The Saw Mill River rises in the Town of New Castle (fig. 1) at an altitude of 500 ft. It flows southward, passes through the City of Yonkers, and empties into the Hudson River at sea level. A streambed profile is shown in figure 2. The last 0.4 miles of the river passes through a covered concrete conduit. The river is 23.5 mi long and drains a narrow basin that is 26.5 mi^2 in area and surrounded by hills, some with steep slopes. It has few tributaries; all are less than 2.0 mi long. The Saw Mill River basin lies in the Manhattan Hills in the New England Upland physiographic province (Cressey, 1966). It is entirely within Westchester County and drains part or all of 12 municipalities.

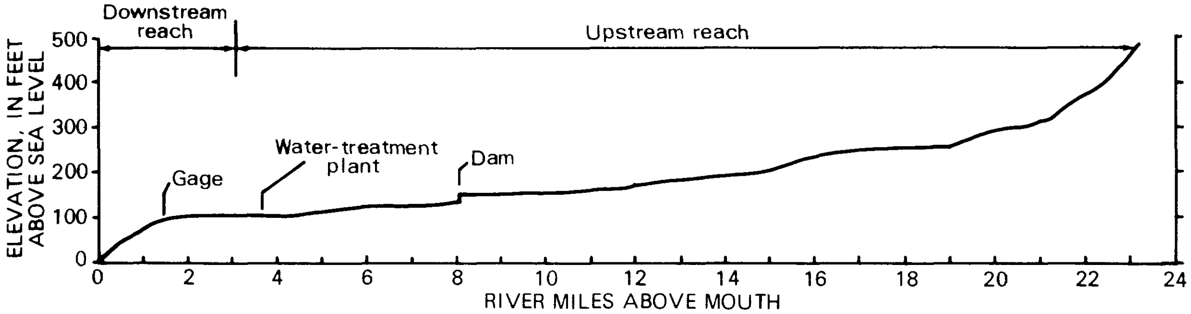


Figure 2.--Elevation profile of the Saw Mill River.

The basin is underlain by metamorphic rocks, primarily gneiss, schist, and marble (Fisher and others, 1970). Bedrock outcrops are common in the basin. The area has been glaciated; till of varying thickness covers much of the higher terrain, and stratified drift and alluvium are found in low-lying areas (Westchester County, 1978).

Climate

The average annual precipitation in the Saw Mill River basin is 46.2 in. (U.S. Army Corps of Engineers, 1979). The mean annual temperature is 52°F (Westchester County, 1978).

Streamflow

The U.S. Geological Survey has maintained a gaging station (no. 01376500) on the Saw Mill River at Yonkers since 1944 (fig. 1). It has been operated continuously since that time except during the first 6 months of the 1974 water year. (The water year extends from October 1 through September 30 of the following calendar year and is identified by the latter year.) The gaging station is 1.2 mi from the mouth of the river, and the drainage area above the gage is 25.6 mi^2. From August 1978 to September 1982, the gaging station was temporarily relocated 1,300 ft downstream from its permanent site because of channel construction. (The effective drainage area above the gage was not significantly changed.) Over the period of record (1944-82), mean discharge of the Saw Mill River at the gage has been 32.3 ft^3/s, and 80 percent of the daily discharges were between 2.7 and 74.0 ft^3/s. The recorded minimum daily discharge is 0.11 ft^3/s, and the recorded maximum instantaneous discharge is 1,020 ft^3/s. The annual extreme high flow can occur at any time during the year. The maximum monthly-mean flow typically occurs in March; the minimum monthly-mean flow is typically in summer or early fall. The monthly mean discharges during 1981 and 1982 are shown in fig. 3.

The discharge of the Saw Mill River at the gage does not include upstream diversions out of the basin by water users. In 1982, for example, 6.26 ft^3/s was the average diversion out of the basin. This amount plus the gaged mean discharge of 28.9 ft^3/s is the total yield of the basin.

Two major impoundments are maintained on the Saw Mill drainage--the Tarrytown Reservoir and Woodlands Lake. The reservoir is on a tributary (fig. 1) and serves as a public water supply for the Village of Tarrytown, which withdrew 266 Mgal during the 1982 water year (Board of Water and Sewer Commissioners, Village of Tarrytown, written commun., 1982). Woodlands Lake is in a county park. A third, smaller impoundment is maintained by the City of Yonkers at river mile 3.2 for a water-treatment-plant intake. During the 1982 water year, 1,207 Mgal of water was withdrawn at this site; monthly mean withdrawals ranged from 5.71 Mgal/d in December to 0.21 Mgal/d in July (James Neary, City of Yonkers Water Supt., written commun., 1982).

Sections of the Saw Mill River have experienced repeated flooding. Consequently, the U.S. Army Corps of Engineers has undertaken several flood-control projects in recent years. One of these, which was in progress during this study, included construction of a concrete channel on a 1.5-mi section of the river in the City of Yonkers. Now completed, the channel is 20 ft wide with 10-ft walls and extends from river mile 1.4 to 2.9. Possible effects of the channel modifications on the results of this study are discussed later.

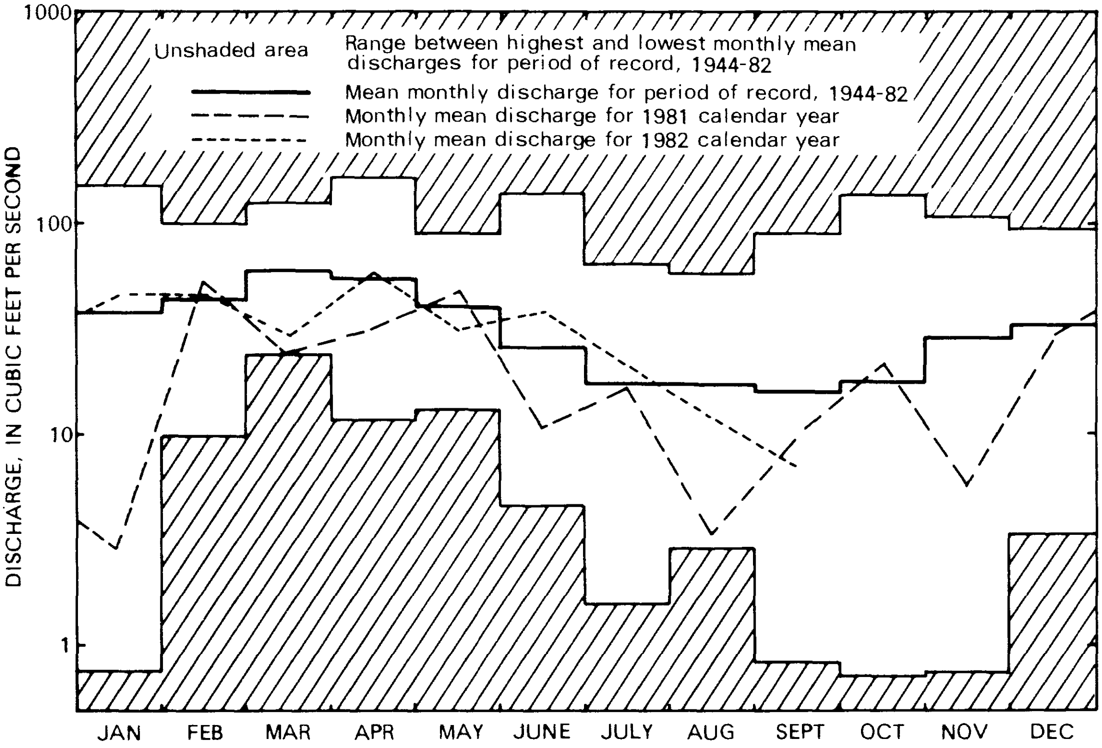


Figure 3.--Monthly streamflow of the Saw Mill River at Yonkers.

River Quality

The State of New York uses a stream-classification system to define stream-water quality and regulate stream use (New York State Department of Environmental Conservation, 1974). The system, which is based on seven physical and chemical standards, defines the best use of the water and provides a basis for regulating the discharge of effluents that could lower the water quality. The system contains five classes ranging from AA to D. Classes AA and A are suitable for drinking-water supplies and all other uses; class B is suitable for bathing and other uses except as a drinking-water supply; class C is suitable for fishing and other uses except bathing and as a drinking-water supply, and class D is suitable for agriculture and industrial cooling and process water and other uses except fishing, bathing, and as a source of drinking water.

The Saw Mill River has been categorized under this system (Westchester County, 1978). The lower reach up to about river mile 3.0 is classified as D; the reach between river miles 3.0 and 9.0 is classified as A, and the reach above river mile 9 is classified as B.

Land Use

Approximately 100,000 people inhabit the Saw Mill River basin, which is mostly urban (Westchester County, 1978). Impervious surfaces cover 38 percent of the basin, but the percentage in the lower basin is much higher than this (Westchester County, 1978). Parks and small wooded areas are most abundant in the northern part. Commercial establishments are scattered throughout the basin; industry is confined primarily to the City of Yonkers, below river mile 4.0. The Saw Mill River Parkway parallels the river along most of its length. The lower few miles of the river are often littered with debris such as tires, shopping carts, bottles, and other trash.

DATA COLLECTION

Sampling Media and Sample Collection

River-bottom sediments were the most extensively used sampling medium in this study for several reasons. Sediments sorb and concentrate heavy metals, nutrients, and many organic compounds, such as pesticides, that enter a river system (Feltz, 1980). Through sorption of such constituents, sediments provide a history of the quality of the water that flows over them. Further comparison of bottom-sediment chemistry among different sites reveals the distribution of constituents in the river and can thus help identify source areas of contaminants. The value of bottom-sediment analysis in determining concentration and distribution of chemical constituents has been demonstrated by many workers, including Rickert and others (1977), Qasim and others (1980), and Lopez-Avila and Hites (1980). Furthermore, contaminants that accumulate in bottom sediments are available to aquatic life and may reach toxic levels. Thus, the chemistry of bottom-sediments provides a measure of river quality.

River water is, in several respects, a less effective sampling medium than bottom sediments for revealing many chemical constituents. First, water samples represent only an instant in time and thus may fail to indicate contaminants from intermittent discharges. Also, compounds that may become highly concentrated in sediment may have low concentrations in water, often below analytical detection limits, and water analyses for these compounds may fail to indicate the river's true condition. For these reasons, most of the sampling in this study was directed to bottom materials rather than river water.

Bottom Sediments

Size fractions.--The concentration of acid-soluble metals in sediment is a function of grain size. (Acid-soluble metals are those solubilized in dilute hydrochloric acid and generally do not include those incorporated in the crystal lattice of the mineral grains.) The relationship between metal concentrations and grain size follows a bimodal distribution. Whitney (1975) found that in five streams in eastern New York, the maximum concentrations of metals were in the silt and clay fraction (<63 µm diameter), with secondary highs in the coarse sand and fine gravel (>1,000 µm diameter). This bimodal distribution results from both the composition of the sediment, which varies with grain size, and the chemical mechanisms that bind the metals to the sediment (Whitney, 1975).

The use of a narrowly defined size fraction of bottom sediments to compare metal concentrations among sites reduces variability caused by site-to-site differences in the grain-size distribution of the sediments. Silt and clay fractions are commonly used to investigate heavy metals or other contaminants in bottom sediments because the fine sediments contain the highest metal concentrations. In this study, however, sediment in the 1,000- to 2,000-µm range was selected (1) because it is less subject to transport than fine sediment and therefore better reflects source areas of heavy metals, as Wilber and Hunter (1979a) documented, and (2) because many reaches of the Saw Mill River are fast moving and have a gravelly or rocky bottom, which makes collection of enough fine sediment for analysis difficult.

Sampling procedures and locations.--Bottom-sediment samples were collected in the streambed at the center of flow where possible. At some sites, however, where fast-moving water keeps the channel scoured, sand and finer sediment could be collected only immediately downstream from boulders or in quieter pools close to the banks. The cobble- and boulder-covered bottom at many sites precluded use of standard bed-material samplers. Therefore, samples were collected at all sites with either a plastic spoon or directly with the sample container. All sampling was done after periods of moderate to low flow, and only the top inch or less of sediment was sampled.

Bottom sediments were sampled at 20 sites, three of which were on tributaries (fig. 1). Some of these sites were used for surface-water and soil sampling also. Sites were selected to provide coverage of the entire river basin (fig. 1 and table 1) and were spaced more closely in the lower reaches to provide detailed coverage of the industrialized area. All sites are designated by an eight-digit U.S. Geological Survey downstream-order identification number, but in this report only the last three digits are used for identification.

Heavy metals.--Ten of the 20 sites were sampled for heavy metals more than once; in total, 36 samples of 1,000- to 2,000-µm sediment were analyzed for heavy metals. To establish the relationship between concentrations and grain size in the Saw Mill River, bottom-sediment samples from six sites (310, 320, 450, 460, 495, and 503) were separated into six size fractions, and each fraction was analyzed for acid-soluble metals. Whole-sediment samples from these sites were also analyzed. (In this report, whole sediment refers to all sediment less than 2,000 µm.)

Organic Compounds.--Bottom sediments were also used to investigate the distribution of synthetic organic compounds in the river. Whole-sediment samples were used for this purpose. Most of the organic compounds investigated are on the USEPA list of "priority pollutants" (Keith and Telliard, 1979). Twelve sites (308, 310, 320, 390, 410, 420, 440, 450, 460, 475, 495, 503) were sampled for pesticides and polychlorinated biphenyls (PCB's); two of these were sampled twice. Bottom sediments at eight sites (320, 410, 420, 450, 470, 495, 503) were sampled for acid- and base/neutral-extractable organic compounds; two of these sites were also sampled twice. (Acid-extractable compounds are extracted with methylene chloride from sediment and water samples under acid conditions prior to analysis; base/neutral-extractable compounds are extracted similarly but under alkaline conditions.)

Nutrients.--Bottom sediments were also analyzed for the major nutrients--nitrogen, phosphorus, and organic carbon. Nutrient analyses were performed on bottom sediment from all but the uppermost site. As with the heavy metals, whole sediment, 1,000- to 2,000-µm sediment, and, from selected sites, finer sediment fractions were analyzed.

Cyanide.--Samples of 1,000- to 2,000-µm bottom sediment from 13 sites (310, 313, 330, 370, 417, 440, 443, 460, 470, 475, 495, 501, 503) and samples of all six size fractions from two sites (460, 495) were analyzed for cyanide.

Table 1.--Location of the 20 sampling sites on the Saw Mill River and tributaries.

[Locations are shown in fig. 1]

Site identification number[1]	Site name	Latitude	Longitude
01376308	Saw Mill River northwest of Chappaqua	41° 10' 36"	73° 46' 47"
01376310	Saw Mill River at Chappaqua	41° 09' 50"	73° 46' 41"
01376313	Tercia Brook at Chappaqua	41° 09' 23"	73° 46' 36"
01376320	Saw Mill River at Pleasantville	41° 07' 55"	73° 47' 47"
01376330	Saw Mill River at Thornwood	41° 07' 28"	73° 47' 03"
01376370	Nanny Hagen Brook at Thornwood	41° 07' 23"	73° 46' 55"
01376390	Saw Mill River at Hawthorne	41° 06' 29"	73° 48' 11"
01376410	Saw Mill River at Eastview	41° 04' 48"	73° 49' 39"
01376415	Saw Mill River near Elmsford	41° 03' 58"	73° 49' 06"
01376417	Mine Brook at Elmsford	41° 03' 57"	73° 49' 00"
01376420	Saw Mill River at Elmsford	41° 03' 19"	73° 49' 15"
01376440	Saw Mill River at Worthington	41° 01' 51"	73° 50' 37"
01376443	Saw Mill River at Woodlands Lake	41° 01' 23"	73° 50' 44"
01376450	Saw Mill River at Mount Hope	40° 59' 09"	73° 51' 54"
01376460	Saw Mill River at Grey Oaks at Yonkers	40° 57' 58"	73° 52' 19"
01376470	Saw Mill River at Old Nepperhan Rd. at Yonkers	40° 57' 18"	73° 52' 28"
01376475	Saw Mill River at Worth St. at Yonkers	40° 57' 05"	73° 52' 41"
01376495	Saw Mill River at Ashburton Ave. at Yonkers	40° 56' 18"	73° 53' 05"
01376501	Saw Mill River off Walsh Rd. at Yonkers	40° 56' 17"	73° 53' 23"
01376503	Saw Mill River at Elm St. at Yonkers	40° 56' 03"	73° 53' 00"

[1] Only the last three digits are used for site identification in this report.

River Water

Although river water was of less concern than bottom sediments in this study, for reasons described earlier, water samples were collected on several different dates to provide information on the water quality of the river.

Chemical analyses.--Sixteen samples from eight sites (310, 320, 420, 440, 450, 460, 495, 503) were analyzed for heavy metals, and 12 samples from the same eight sites for major nutrients. Dissolved and total concentrations of both metals and nutrients were measured. (Dissolved constituents are defined as those that pass through a 0.45-µm filter.) Water samples collected at each of four sites (320, 420, 460, 503) on two dates were analyzed for total concentrations of pesticides, PCB's, and acid- and base/neutral-extractable organic compounds. In addition, nine samples from five sites (320, 420, 460, 495, 503) were analyzed for volatile organic compounds on the USEPA "priority pollutant" list, and 11 samples, one from each of 11 sites (310, 320, 390, 410, 420, 440, 443, 450, 460, 495, 503), was analyzed for total phenols.

Sampling procedures.--All water samples were single-vertical-dip samples collected at the visual center of flow except at site 460, where deep water in the impoundment required collection closer to the bank. Metal and nutrient samples were collected directly with a sample splitter and then distributed to bottles. Along most reaches, the stream was too shallow for depth-integrating collection techniques. Samples for organic carbon and nonvolatile organic-compound analyses were collected directly in the sample bottles; samples for volatile compounds were collected in glass septum bottles and capped under water to exclude air from the sample and prevent escape of volatiles. (Volatile organic compounds are stripped as a vapor from the water sample by an inert gas prior to analysis.) All water samples were collected under moderate to low-flow conditions.

Soils

Chemical analyses.--Soils are the source of stream-bottom sediments; consequently, the heavy-metals concentration in stream sediments is partly a function of the heavy-metals content of the soil particles that enter the stream. Soil samples from 10 sites (320, 410, 415, 440, 450, 460, 470, 495, 501, 503) were analyzed for five heavy metals to aid interpretation of the heavy-metal chemistry of the bottom sediments. Both 1,000- to 2,000-µm soil fractions and whole soil (<2,000 µm) were analyzed.

Sampling procedures.--Soil sites were selected to cover the entire length of the river and were more closely spaced in the lower section of the basin. Six of the sites are subject to direct runoff from roads, parking lots, or other impervious surfaces. All soil samples but one were collected along the Saw Mill River; the exception was collected near a small tributary that enters the river near site 410 (fig. 1). All samples were collected within 200 ft of the river bank. The soil sites were assigned the same number as the closest river-sampling site.

The soil was sampled by first loosening the top 6 in. of soil with a steel shovel, then collecting by hand a sample of material that had not come into contact with the shovel.

Ceramic Tiles

To complement the investigation of the heavy-metal chemistry of the river, unglazed ceramic tiles were placed in the river for study of the accretion of iron-manganese oxides and associated heavy metals onto their surfaces. The method, which is considered experimental, is based on work by Carpenter and Hayes (1978, 1980), who proposed it as a geochemical exploration method. The technique is similar to using bottom sediments to assess river quality but eliminates four variables inherent to bottom-sediment assessments--substrate surface area, surface composition, site of accretion, and period of accretion. Some variability among sites remains, however; for example, the types of algal coatings that may develop on the substrates can vary with time and differ among sites. (Algae can serve to accumulate heavy metals (Laube and others, 1979) but also prevent the deposition of oxide coatings on the substrates.) Also, the tiles may become buried by sediment, which greatly reduces the rate of oxide deposition or may cause existing coatings to dissolve.

Unglazed ceramic tiles (2 x 2 in.) were used in the study. The tiles were prepared by simmering in concentrated hydrochloric acid for 3 hours and were then attached to an 8- x 8- x 14-in. concrete block by silicone rubber sealant. Each block contained 36 tiles. One block was placed in the river at each of seven sites: 320, 410, 443, 450, 470, 495, and 503. Blocks were lost at sites 470, 495, and 503 during the study; replacement sets were emplaced at sites 495 and 503. Four tiles were removed from each block at approximately 6-week intervals. A control block of tiles identical to those used in the river was kept immersed in deionized water in the laboratory and was analyzed at the same interval as the field tiles.

Sample Preparation and Analyses

Sample Preparation

Bottom Sediments.--Bottom sediments were prepared for chemical analysis by wet sieving. When only a whole-sediment or 1,000- to 2,000-µm sample was required, the sample generally was sieved with river water at the site. Sediments that were separated into multiple size fractions, and those to be analyzed for pesticides, were sieved in the laboratory with river water collected at the time of sampling. In the laboratory, sediment was washed through sieves by repeatedly passing river water over them. The finest sediment was allowed to settle, and the water was then decanted. In addition to the 1,000- to 2,000-µm fraction, sediments from six sites were separated into the following fractions: 500- to 1,000-µm, 250- to 500-µm, 125- to 250-µm, 63- to 125-µm, and <63-µm. A whole-sediment sample from all six sites was also prepared.

Sediment samples to be analyzed for nutrients, synthetic organic compounds, and cyanide were chilled from the time of collection; the other samples were stored at room temperature until analysis. Sediments to be analyzed for synthetic organic compounds were collected and stored in heat-treated glass jars; all other sediment samples were stored in plastic containers.

Soil.--Soil samples were sieved with deionized water in the laboratory and were stored at room temperature until analysis.

River water.--Water samples to be analyzed for dissolved components were filtered through 0.45-μm filters soon after collection. Silver filters were used for the dissolved organic carbon samples; membrane filters were used for all other samples. Samples to be analyzed for organic carbon and synthetic organic compounds were stored in heat-treated glass bottles. Samples for nitrogen and phosphorus analysis were preserved with mercuric chloride and stored in brown polyethylene bottles. Samples for metals analysis were acidified with nitric acid to pH 2 or less and stored in polyethylene bottles. Samples for phenols analysis were preserved with copper sulfate and phosphoric acid and stored in glass bottles. Samples for synthetic organic compound analysis were collected and stored in heat-treated glass bottles. All water samples except those for metals analysis were chilled from the time of collection to the time of analysis.

Temperature, specific conductance, and pH were measured in the field at the time of sample collection.

Ceramic tiles.--Leachates from the ceramic tiles were prepared in the Geological Survey laboratory in Albany, N.Y. by a method similar to that described by Carpenter and Hayes (1978). In the laboratory, the backs of the tiles were scraped with a plastic knife to remove the silicone sealant and were cleaned further with silicon carbide paper to remove any precipitate from that surface. The tiles were then rinsed with deionized water and gently rubbed with the fingers to remove loosely adhered sediment and organic material, but not the oxide coating. After rinsing, they were placed in a beaker with 150 mL of dilute (1:4) hydrochloric acid and heated to 75°C for 4 hours. The resulting leachate was diluted to 500 mL with deionized water and analyzed for dissolved heavy metals.

Chemical Analyses

All chemical analyses were performed by the U.S. Geological Survey National Water Quality Laboratory in Doraville, Ga. Water, sediment, and soil samples were analyzed for heavy metals, cyanide, and nutrients by methods described in Skougstad and others (1979) and Fishman and Bradford (1982). Phenols in water were analyzed by the method described in Goerlitz and Brown (1972). Acid- and base/neutral-extractable organic compounds, listed in table 2, were analyzed with a gas chromatograph/mass spectrometer by USEPA method 625 (U.S. Environmental Protection Agency, 1979b) or an adaptation of that method, which does not distinguish between anthracene and phenanthrene. Volatile organic compounds, listed in table 3, were analyzed by a purge and trap technique and a GC/MS system (U.S. Environmental Protection Agency, 1979a). Pesticides and other chlorinated hydrocarbons, listed in table 4, were analyzed with a gas chromatograph by an electron-capture detector (U.S. Environmental Protection Agency, 1979b; Goerlitz and Brown, 1972). The PCB analysis determined only gross concentration; it did not differentiate the Aroclors[1]. Organophosphorous pesticides (table 4) were analyzed with a gas chromatograph mated with a flame photometric detector.

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[1] Use of brand names herein is for identification purposes only.

Grain-Size Analyses

Grain-size analyses of bottom sediments were done by dry sieving at the U.S. Geological Survey sediment laboratory in Columbus, Ohio. The size fractions measured were the same as those separated for chemical analyses.

Table 2.--Acid- and base/neutral-extractable organic compounds for which water and bottom-sediment samples were analyzed.

[All compounds are on U.S. Environmental Protection Agency priority-pollutant list; source: Beetem and others, 1981. Detection levels are approximately 1 μg/L for water plus suspended sediment and approximately 20 μg/kg for bottom sediment.]

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*-octyl phthalate
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

Table 3.--Principal volatile organic compounds for which water samples were analyzed.

[All compounds are on U.S. Environmental Protection Agency priority pollutant list. Detection level approximately is 1 μg/L. Source: Beetem and others, 1981.]

Volatile Organic Compounds

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-Dichloropropane
Ethylbenzene
Methylbromide
Methylene chloride
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Toluene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Trichlorofluoromethane
Vinyl chloride

Table 4.--Organochlorine and organophosphorous compounds for which water and bottom-sediment samples were analyzed.

[NA - water samples not analyzed for these compounds. Source: Beetem and others, 1981.]

Compound	Detection level Water plus suspended sediment (μg/L)	Bottom sediment (μg/kg)
Aldrin	0.01	0.1
Chlordane	.1	1
DDD	.01	.1
DDE	.01	.1
DDT	.01	.1
Diazinon	NA	.1
Dieldrin	.01	.1
Endosulfan	.01	.1
Endrin	.01	.1
Ethion	NA	.1
Gross PCB	.1	1
Gross PCN	.1	1
Heptachlor	.01	.1
Heptachlor epoxide	.01	.1
Lindane	.01	.1
Malathion	NA	.1
Methoxychlor	.01	.1
Methyl parathion	NA	.1
Methyl trithion	NA	.1
Mirex	.01	.1
Perthane	.1	.1
Parathion	NA	.1
Toxaphene	1	1
Trithion	NA	.1

CHEMICAL QUALITY OF SAW MILL RIVER

Nutrients

River Water

Nitrogen and phosphorus are commonly the nutrients that limit plant growth. Nitrogen, phosphorus, and carbon concentrations in water samples are presented in table 16 (at end of report). (As a consequence of normal analytical error, the dissolved concentration reported for a constituent is sometimes slightly greater than the total concentration of that constituent.) The generality of the following observations is restricted by the small number of analyses made for nutrients.

Dissolved forms of nitrogen constituted most, if not all, of the total concentration of the various nitrogen species in the water samples tested. By comparison, dissolved forms of phosphorus contributed a smaller percentage, about half, of the total phosphorus, and dissolved organic carbon contributed about 70 percent of the total organic carbon. The most abundant forms of nitrogen in the water samples were dissolved organic nitrogen (0.30 to 1.5 mg/L as nitrogen) and dissolved nitrate (0.48 to 1.6 mg/L as nitrogen); minor by comparison were dissolved ammonia (0.03 to 0.44 mg/L as nitrogen) and dissolved nitrite (0.01 to 0.06 mg/L as nitrogen). Approximately 60 percent of the dissolved phosphorus was in the form of orthophosphate. Organic carbon concentrations were in the normal range for stream waters.

Neither nitrate, nitrite, nor un-ionized ammonia were detected in concentrations exceeding U.S. Environmental Protection Agency (1977) water-quality criteria or New York State Department of Health (1977) standards for sources of water supplies.

Availability of nutrients can cause excessive algal growth, but many other factors limit algal growth, especially in streams. Consequently, no generally accepted standard to prevent nuisance growth have been established for nitrogen and phosphorus. Phosphorus concentrations of 0.1 mg/L or greater may interfere with coagulation processes in water-treatment plants (Mackenthun, 1973, p.123). A total phosphorus concentration of 0.1 mg/L been suggested as a desired goal for rivers that do not discharge into lakes or impoundments (Mackenthun, 1973, p. 176). Phosphorus concentrations in the Saw Mill River exceed 0.1 mg/L at times, but no excessive algal growth was apparent in the river.

Bottom Sediments

Nitrogen, phosphorus, and carbon concentrations in bottom sediments are presented in table 17 (at end of report). Analyses of multiple size fractions of bottom sediment from six sites indicate that the relationships between concentration and grain size for nitrogen, phosphorus, and organic carbon follow a bimodal distribution--that is, nutrient concentrations in the 1,000- to 2,000-μm sediment are greater than in 250- to 1,000-μm fractions, but the highest concentrations are in fractions smaller than 250 μm. (Site 320 may be an exception.) Phosphorus and organic carbon show this bimodal relationship most strongly.

Concentrations of nutrients in both water and sediments do not vary significantly among sites. The spatial variations follow no discernible trends except for dissolved orthophosphate, which was slightly more concentrated in the lower third of the river. Phosphates may enter rivers from several sources, including human and animal excrement, phosphate detergents, industrial wastewaters, and leaves.

Heavy Metals

River Water

Water analyses for heavy metals are presented in table 18 (at end of report). The data are limited but suggest a downstream increase in heavy metals in the river water. A high percentage of the total heavy metals carried by the river is carried on suspended matter, especially iron, lead, and zinc, of which at least 85 percent is borne on suspended matter.

Manganese was the only metal that regularly exceeded the U.S. Environmental Protection Agency (1977) water-quality criterion of 50 µg/L for domestic water supplies (which applies to the dissolved metal only). This limit is based on esthetic, rather than health, considerations, namely that manganese concentrations greater than 150 µg/L can stain laundry and affect the taste of beverages. Manganese did not, however, exceed the New York State Department of Health (1977) standard of 300 µg/L for sources of water supplies, nor did any of the other metals investigated in this study.

Collectively the water analyses provide evidence of a downstream deterioration in water quality. The four highest concentrations of total recoverable lead and zinc and the two highest concentrations of dissolved lead and zinc were found in the lowest 4 miles of the river. The two highest concentrations of total-recoverable and dissolved copper were downstream of river mile 3. Three of the four cadmium concentrations above the detection limit (1 µg/L) and the only two arsenic concentrations above the detection limit (1 µg/L) were in samples collected downstream from river mile 4.

Bottom Sediments

Heavy-metal concentrations in six size fractions of bottom sediment from six sites along the full length of the river are listed in table 5. All size fractions from four sites (310, 320, 450, and 503) were also analyzed for arsenic and mercury, but concentrations of these metals were below the detection limits of 1 µg/g and 0.01 µg/g, respectively.

Concentration in relation to sediment size.--The concentrations of acid-soluble metals are, in general, highest in the finest size fraction. They decrease with increasing grain size over the next two or three fractions, but in the 1,000- to 2,000-µm sediment they typically exceed those in the 500- to 1,000-µm or 250- to 500-µm fractions. (See fig. 4.) This finding is consistent with those of Whitney (1975) and Wilber and Hunter (1979a).

Table 5.--Heavy-metal concentrations is size fraction of bottom sediments from the Saw Mill River, 1981.

[Analyses by U.S. Geological Survey. Concentrations in micrograms per gram of dry sediment; site locations shown in fig. 1.]

Size fraction	Site number	Dry-weight percentage in whole sediment [1]	Cd	Cr	Cu	Fe	Pb	Mn	Zn
1,000–2,000 µm	310	4.2	<1	20	--	15,000	49	390	--
	320	11.6	2	<10	11	4,700	54	490	33
	450	19.9	<1	20	16	10,000	52	190	50
	460	15.6	<1	<10	<10	1,900	30	32	11
	495	10.8	<1	<10	100	1,900	60	73	47
	503	23.9	2	<10	27	9,500	280	250	110
500–1,000 µm	310	33.9	<1	10	15	5,000	14	160	30
	320	33.7	1	<10	5	2,600	38	210	24
	450	37.4	<1	25	31	6,000	38	120	50
	460	21.0	<1	<10	<10	1,900	10	30	7
	495	27.4	<1	<10	100	1,800	70	72	94
	503	38.7	1	<10	100	4,800	150	260	110
250–500 µm	310	48.9	<1	<10	5	3,900	12	140	20
	320	42.2	2	<10	35	4,000	83	170	35
	450	30.2	<1	<10	8	4,900	68	160	30
	460	31.5	<1	<10	<10	2,900	10	52	14
	495	43.1	<1	<10	80	2,300	40	66	70
	503	22.0	2	<10	80	2,000	60	70	45
125–250 µm	310	8.3	<1	40	26	14,000	68	460	90
	320	10.5	2	20	23	10,000	330	350	90
	450	9.6	<1	20	12	12,000	120	500	40
	460	21.6	<1	10	10	5,400	20	88	26
	495	15.1	<1	<10	130	3,000	140	73	77
	503	7.8	2	10	140	5,500	180	140	110
63–125 µm	310	1.7	<1	100	110	30,000	140	900	230
	320	1.3	7	90	43	6,500	270	290	120
	450	1.4	<1	50	30	11,000	87	590	110
	460	6.2	1	30	20	14,000	60	270	87
	495	2.3	<1	30	230	8,100	560	220	140
	503	4.4	6	20	74	9,700	230	210	150
<63 µm	310	2.9	3	60	39	25,000	110	840	180
	320	0.8	11	150	210	25,000	350	1,200	520
	450	1.4	<1	80	88	28,000	280	2,000	300
	460	4.1	<1	65	60	24,000	170	680	220
	495	1.3	3	60	500	23,000	570	830	470
	503	3.2	5	50	170	18,000	440	560	400
<2,000 µm	310	--	<1	10	6	7,100	27	220	30
	320	--	1	20	75	11,000	240	330	130
	450	--	<1	10	11	5,000	58	100	40
	460	--	<1	<10	10	4,300	30	100	33
	495	--	<1	<10	90	2,400	80	75	78
	503	--	1	10	81	6,800	160	180	150

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[1] Whole sediment = <2,000 µm.

The higher metal concentrations in 1,000- to 2,000-μm sediment are attributed to thicker iron- and manganese-oxide coatings on the coarse sediment than on the fine sediment (Whitney, 1975) and may be attributed to heavier coatings of organic matter on the larger grains as well. Conditions for oxide deposition and associated heavy-metal sorption have been found generally more favorable in shallow, fast-flowing reaches of streams than elsewhere (Whitney, 1975). Site 320, in the upper 3 miles of the river, and site 503, the lowermost site, for example, are on shallow, swift reaches with sand and gravel bottoms, and the relationship between concentration and grain size for these sites, plotted in figure 4, is clearly bimodal. Site 460, conversely, is on a reach that is impounded for the City of Yonkers water-treatment plant (fig. 1). The water here is relatively deep (>3 ft) and slow moving, and the bottom sediment at the site has a relatively high silt and clay content. (See table 6.) Concentrations of heavy metals in the 1,000- to 2,000-μm sediment at this site were much lower than in the finer sediments.

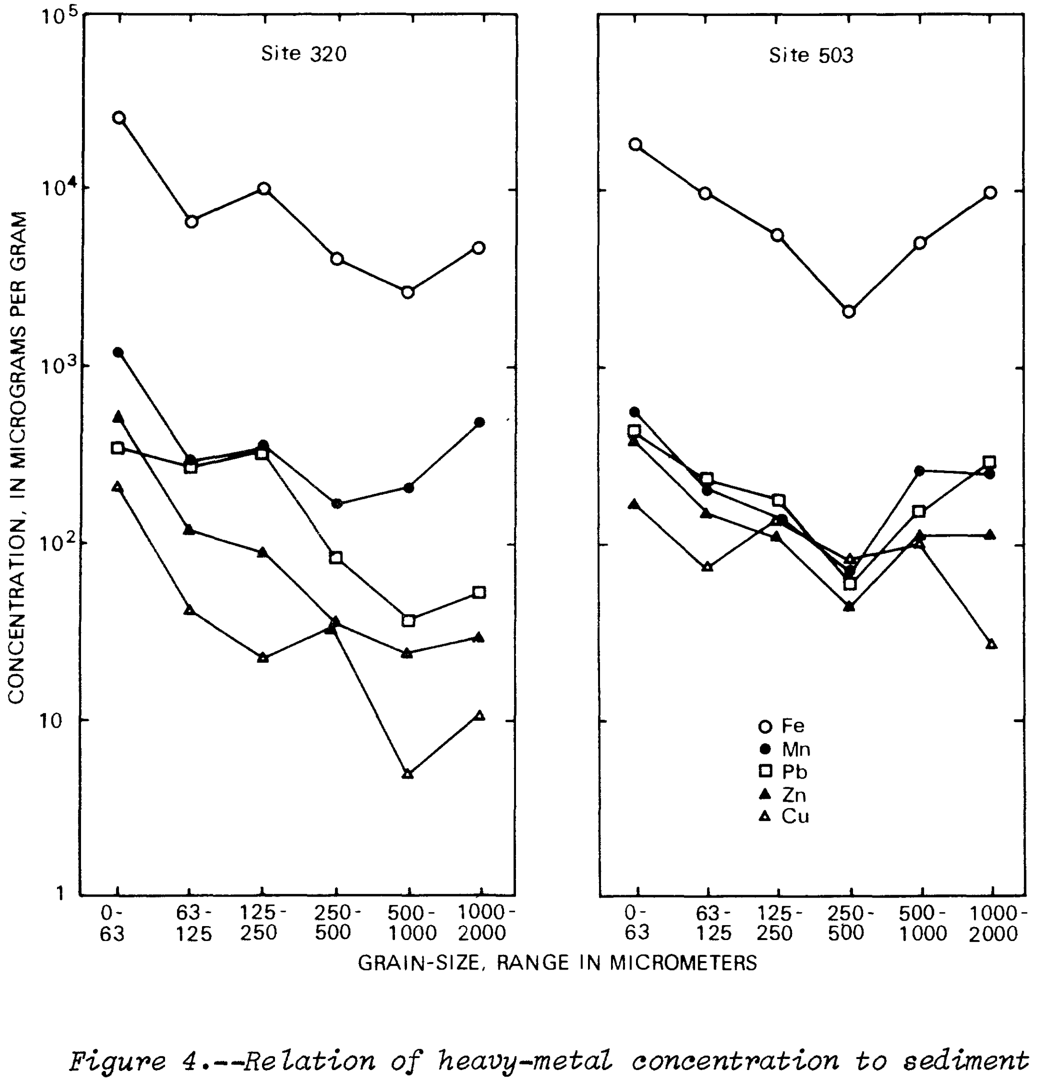

Figure 4.--Relation of heavy-metal concentration to sediment grain size at site 320, near upper end of basin, and site 503, near lower end of basin.

The sediment fraction having the greatest quantities of heavy metals in the entire river is the 250- to 1,000-µm range, the most abundant sediment size. Concentrations at all sites are given in table 5; the particle-size distribution at all sites is summarized in table 6.

Table 6.--Dry-weight percentage of sediment size fractions in river-bottom sediments from Saw Mill River and tributaries, 1981.

[Site locations are shown in fig.1]

Site number	Date collected	Particle-size range (µm) 1,000-2,000	500-1,000	250-500	125-250	63-125	<63
310	05-12-81	4.2	33.9	48.9	8.3	1.7	2.9
313	08-12-81	15.8	26.2	29.9	13.1	6.6	8.3
320	02-10-81	11.6	33.7	42.2	10.5	1.3	.8
330	08-11-81	8.8	38.5	38.4	9.4	3.0	2.0
370	08-11-81	19.4	45.1	29.2	5.5	.4	.4
390	05-11-81	[1]SD	----	----	----	----	----
410	05-11-81	21.9	30.5	33.3	11.7	1.8	.9
415	08-11-81	6.8	33.6	43.6	12.9	1.0	2.0
417	08-11-81	26.4	38.1	27.9	6.5	.7	.3
420	05-11-81	11.3	47.7	37.2	3.2	.3	.3
440	05-11-81	16.7	44.2	22.0	12.0	2.4	2.7
450	05-11-81	19.9	37.4	30.8	9.6	1.4	1.4
460	08-12-81	15.6	21.0	31.2	21.6	6.2	4.1
470	08-12-81	35.1	29.5	22.9	8.8	2.7	1.1
475	05-11-81	26.0	27.8	37.2	7.4	.7	1.0
495	08-12-81	10.8	27.4	43.1	15.1	2.3	1.3
501	08-12-81	16.6	32.4	40.6	9.2	.7	.4
503	02-10-81	23.9	38.7	22.0	7.8	4.4	3.2

[1] SD = Sample destroyed by laboratory.

Concentration patterns.--Analyses of 36 samples of 1,000- to 2,000-µm bottom sediment from all sites are presented in table 7. Concentrations of arsenic, cadmium, chromium, cobalt, mercury, and nickel were, in general, near or less than their respective analytical detection limits. Marked differences were found within sites where multiple samples were collected, which demonstrates the qualitative nature of bottom-sediment chemistry. Some of the variation at site 495 (river mile 1.5) may be a consequence of the aforementioned channel construction at and near the site.

Table 7.--Heavy-metal concentrations in 1,000- to 2,000-μm bottom sediment from the Saw Mill River and tributaries, 1981-82.

[Analyses by U.S. Geological Survey. Concentrations in micrograms per gram of dry sediment; site locations are shown in fig. 1.]

Site number	Date collected	As	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Ni	Zn
308	11-17-81	--	<1	9	--	2	3,300	10	240	--	20	23
310	05-12-81	<1	<1	20	--	--	15,000	49	390	<0.01	--	--
	08-12-81	--	<1	<10	<10	10	6,000	90	190	--	10	28
313	08-12-81	--	1	10	10	10	5,800	20	200	--	10	42
320	02-10-81	<1	2	<10	--	11	4,700	54	490	<.01	--	33
	05-11-81	<1	4	30	--	18	9,300	93	260	<.01	--	70
	08-24-82	--	<1	3	<10	4	1,000	20	150	--	<10	25
330	08-11-81	--	1	<10	<10	10	4,300	20	96	--	10	33
370	08-11-81	--	1	<10	<10	10	4,000	70	240	--	<10	33
390	08-11-81	<1	1	<10	--	12	8,700	23	160	<.01	--	40
410	05-11-81	<1	<1	<10	--	12	9,800	21	310	<.01	--	50
	08-24-82	--	<1	2	<10	2	880	10	220	--	<10	17
415	08-11-81	--	<1	<10	<10	10	5,500	10	150	--	10	37
417	08-11-81	--	<1	10	10	10	4,300	30	150	--	10	56
420	08-12-81	<1	<1	10	--	15	11,000	42	340	<.01	--	80
440	05-11-81	<1	<1	<10	--	9	6,800	110	120	<.01	--	40
	08-12-81	--	<1	<10	<10	10	5,700	20	96	--	10	39
443	09-01-81	--	<1	8	<10	9	5,100	25	320	--	10	33
	08-24-82	--	<1	6	<10	33	2,200	30	180	--	<10	24
450	05-11-81	<1	<1	20	--	16	10,000	52	190	<.01	--	50
	08-24-82	--	<1	8	<10	5	1,500	20	84	--	<10	19
460	08-12-81	--	<1	<10	<10	<10	1,900	30	32	--	<10	11
470	08-12-81	--	1	20	<10	70	4,800	90	200	--	10	190
	08-24-82	--	<1	6	<10	45	920	50	82	--	<10	33
475	05-11-81	<1	<1	10	--	37	10,000	140	200	<.01	--	90
	08-12-81	--	<1	10	<10	20	4,900	90	120	--	<10	94
495	05-11-81	<1	3	70	--	83	12,000	500	460	<.01	--	240
	08-12-81	--	<1	<10	<10	100	1,900	60	73	--	<10	47
	11-17-81	--	<1	7	--	20	2,800	20	88	--	10	63
	04-21-82	--	<4	6	<10	340	3,300	50	110	--	<10	230
	08-24-82	--	1	10	<10	23	2,400	60	180	--	10	54
501	08-12-81	--	2	<10	<10	50	5,200	470	140	--	10	660
503	02-10-81	<1	2	<10	--	27	9,500	280	250	<.01	--	110
	05-11-81	<1	<1	10	--	20	11,000	33	360	<.01	--	60
	08-12-81	--	1	10	<10	50	5,500	120	290	--	<10	350
	08-24-82	--	1	3	<10	13	1,600	70	120	--	<10	71

Downstream increases in heavy-metals concentration along the river are discernible despite the variability within each site. For example, the highest concentrations of copper, lead, and zinc were downstream of river mile 3.0 (fig. 5), in the most heavily developed area. Iron and manganese exhibit no trends, however. (See fig. 5.)

Dividing the mean metal concentrations in sediments from below site 460, just above the Yonkers water-treatment plant, by the mean concentrations of sediments from site 460 and above gave a ratio of 4.0 for copper, 3.8 for lead, and 3.9 for zinc. The ratios for iron and manganese were both 0.9.

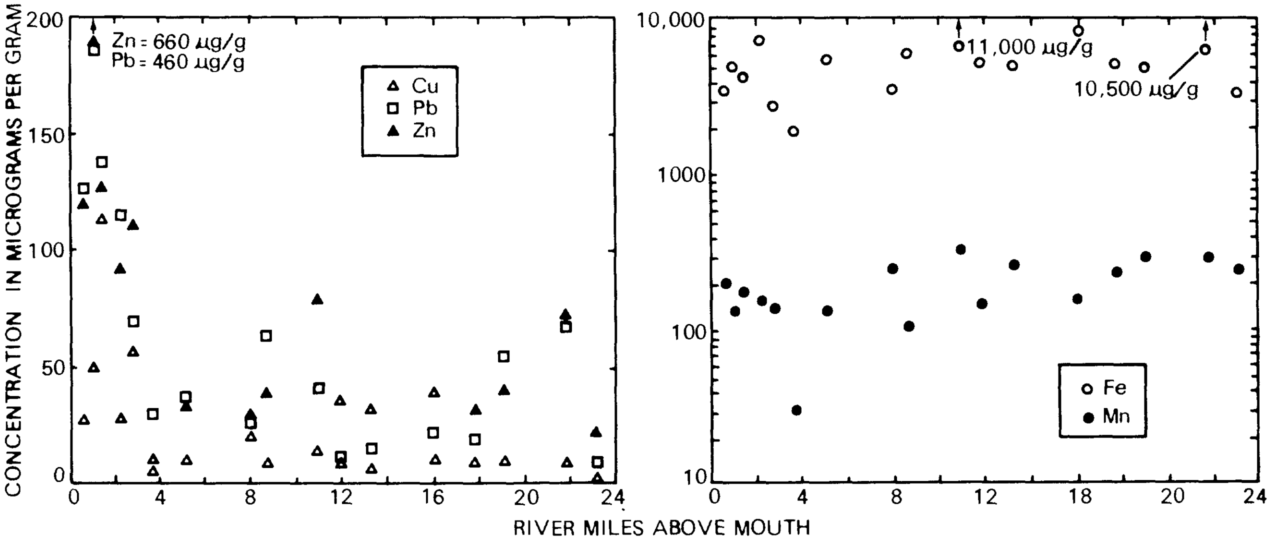

Figure 5.--Heavy-metal concentrations in 1,000- to 2,000-µm bottom sediment in the Saw Mill River.
Left: Copper, lead, and zinc. Right: Iron and manganese.

<u>Location of metal sources</u>.--The statistical distribution of heavy-metal concentrations in the bottom sediments can provide clues as to the sources of the metals. If a metal is derived solely from a geological or other natural source, its concentration in the bottom sediments will follow either normal or log-normal frequency distribution (Davies, 1980). The metals investigated here can be assumed to have at least one natural source within the drainage basin. Further, if only one source of the metal is acting throughout the entire basin, concentrations of the metal in the bottom sediments will belong to one statistical population and will be randomly distributed throughout the basin. If some concentrations are anomalously high, however, they may belong to a different statistical population, which may suggest an additional source within the basin, as Rickert and others (1977) demonstrated.

Statistical analyses were performed to determine whether the higher copper, lead, and zinc concentrations in the downstream reaches of the river were indicative of additional sources. The iron and manganese values were analyzed for comparison. Again, the sampling sites were divided into two groups. The five sites below river mile 3.0, which were expected to contain contaminated sediments, form the downstream group, and the 15 sites at and above river mile 3.7 form the upstream group. Because the copper concentration at site 460, the lowermost of the upstream group, was below the detection limit of 10 μg/g, a value of 9 μg/g was substituted. Also, the anomalously high copper value of 340 μg/g for site 495, in the downstream group, was suspected to represent an analytical error and was eliminated from the analysis. These adjustments present the "worst case" for distinguishing between upstream and downstream differences in copper concentrations. That is, the adjustments result in closer mean copper values and decrease the variance within each group. Consequently, the two copper groups are more similar than if the 340-μg/g value had been retained and if a value of 5 μg/g had been used for the value below the detection limit.

Most of the copper, lead, zinc, iron, and manganase groups, both upstream and downstream, fit log-normal distributions better than normal distributions. The exceptions are the upstream iron and manganese groups, but in both of these, the difference between the goodness-of-fit to normal distributions and to log-normal distributions is slight. Thus, all groups were treated as log-normal distributions, and log transforms of the analyses were used in the subsequent statistical tests.

If the means or variances of the upstream and downstream concentrations of a given metal are significantly different, two or more sources can be assumed. The F-test was used to compare variances, and the t-test was used to compare means. At the $\alpha = 0.01$ level of significance (the 99-percent confidence level), the variances of the upstream concentrations of the five metals do not differ from the downstream variances. The means of the upstream and downstream concentrations of copper, lead, and zinc are different, however, at the $\alpha = 0.01$ level of significance. That is, one can be 99-percent confident that the means are different and, presumably, that two or more sources are contributing each of these three metals. At the $\alpha = 0.10$ level of significance, neither the means of iron nor of manganese differ from upstream to downstream. In other words, no more than one significant source of iron or manganese is indicated to be supplying these metals to the river-bottom sediments.

Correlation coefficients between all possible paired combinations of copper, iron, lead, manganese, and zinc in both upstream and downstream groups of sites are presented in table 8. Coefficients for the upstream group are to the right of the diagonal, and those for the downstream group to the left. The upstream sites show significant correlations between iron and manganese, iron and zinc, and manganese and zinc. The downstream sites show significant correlation between lead and iron, lead and manganese, lead and zinc, and iron and manganese. The correlation of iron with manganese in both upstream and downstream sediments suggests that the two metals originate primarily from natural sources that supply the metals at about the same rate throughout the basin, and that the concentrations of neither are significantly affected by secondary sources. In contrast, the disparity between upstream and downstream correlations of lead and zinc with other metals suggest that other sources of these two metals are operating in different parts of the basin.

Table 8.--Correlation coefficients of heavy metals in upstream and downstream bottom sediments from the Saw Mill River and tributaries, 1981-82.

[Coefficients for sediments from upstream of river mile 3.0 are right of diagonal; coefficients for sediments from downstream of river mile 3.0 are left of diagonal.]

	Cu	Fe	Pb	Mn	Zn
Cu[1]	--	0.329	0.238	0.119	0.338
Fe	0.050	--	0.346	0.473*	0.877†
Pb	0.348	0.528**	--	0.164	0.262
Mn	0.154	0.848†	0.495**	--	0.500*
Zn	0.247	0.133	0.675†	0.151	--

[1] Data in table 10; calculated without using the 340 μg/g Cu for site 495.

** Statistical significance of $\alpha < 0.10$

* Statistical significance of $\alpha < 0.05$

† Statistical significance of $\alpha < 0.01$

Soils

Soil analyses for acid-leachable heavy metals are listed in table 9. Soils from sites 320, 450, 470, 495, 501, and 503, all of which were subject to runoff from roads, parking areas, or industrial areas, had generally higher concentrations of copper, lead, and zinc than soils from the other four sites. Like the river-bottom sediments, soils from the lower four sites contained the highest concentrations of copper, lead, and zinc; this trend did not hold for iron or manganese. The high lead concentrations at site 501 cannot be explained.

In general, heavy-metal concentrations in the soils were comparable to metal concentrations in the river-bottom sediments. (See tables 7 and 9.) Therefore, the heavy-metal chemistry of the bottom sediments could result largely from the direct transport of soil particles into the river. Bottom sediments in the downstream sites had higher copper and zinc concentrations than soils from the same sites, however, which suggests thay these metals are being contributed from sources other than soils.

Table 9.--Heavy-metal concentrations in soils from the Saw Mill River basin, 1981.

[Analyses by the U.S. Geological Survey. Concentrations in micrograms per gram of soil; Concentrations are of acid-leachable metals, not total concentrations. Site locations are shown in fig. 1]

Site-identification number[1]	Sample type[2]	Concentrations				
		Cu	Fe	Pb	Mn	Zn
320	whole	18	8,300	170	380	100
410	whole	26	6,600	40	220	26
	fraction	14	4,300	20	120	15
415	fraction	10	4,400	50	270	47
440	fraction	18	4,500	50	420	42
450	whole	32	5,700	120	250	110
	fraction	21	4,000	120	130	39
460	whole	17	7,100	20	310	31
	fraction	10	5,600	10	140	21
470	whole	42	5,300	180	170	110
	fraction	20	3,900	90	91	60
495	whole	40	3,600	280	200	110
	fraction	25	4,200	210	140	83
501	whole	52	4,500	1,100	200	250
	fraction	20	5,200	1,900	110	280
503	fraction	96	3,900	210	160	160

---

[1] Soil sampling sites are identified by the closest river sampling sites; all soil samples were collected within 1,000 ft of the river site and most within 200 ft.

[2] Whole samples include all soil materials <2,000 µm; fraction samples include only 1,000- 2,000-µm grains.

Ceramic Tiles

Most ceramic tiles had developed brown to black coatings of iron and manganese oxides within 6 weeks after they were emplaced in the river in April 1982. Tiles that became buried by sediment soon after emplacement formed little or no coating, however, and tiles that became buried after coatings had formed exhibited a blotchy appearance that suggests partial dissolution of the coating during burial. Only tiles found above the sediment line at the time of collection were removed for analysis. The extent and frequency of burial varied among sites and was a function of the sediment composition of the streambed.

Periphyton coatings developed on the tiles within a few weeks after they were emplaced. Algal growth increased through the summer and began to decrease in the fall; some periphyton remained into the winter. Periphyton on tiles at the two lowermost sites (495 and 503) consisted solely of slimes and was markedly less abundant than at sites upriver, which may be a reflection of differences in water quality.

Analyses of the ceramic-tile coatings are presented in table 10. Seven sets of analyses are given for the four upstream sites; fewer analyses are available for the lower three sites. Analyses of the original tiles and a replacement set are presented for site 495; analyses of control tiles kept in the laboratory are included.

Ceramic tiles have an advantage over coarse bottom sediments in that they more readily collect detectable and distinguishable quantities of the minor metals such as cadmium and cobalt. (Compare tables 7 and 10.)

Significant chemical differences are apparent between coatings formed on the tiles and those formed on the bottom sediments. The most notable difference is the ratio of iron to manganese. In the 1,000- to 2,000-μm bottom sediments, iron concentrations are at least 25 times greater than the manganese concentrations, whereas on the tiles, the manganese concentration greatly exceeds that of iron. This observation agrees with findings by Carpenter and others (1975), who found iron-to-manganese ratios on boulder coatings to be much lower than those on bottom sediments from the same location. Carpenter and Hayes (1980) later found iron-to-manganese ratios of coatings on submerged tiles to be similar to those in boulder coatings in the same stream. The ratios of other metals in both tile and boulder coatings in that study also differed significantly from those of leachable metals in bottom sediments.

The tile analyses indicate that, after a rapid buildup of metals during the first 6 weeks, the accretion rate declined and varied with time. Metal concentrations at some sites decreased between tile collections. Carpenter and Hayes (1980) noted similar variations with time. These variations could result from several factors; for example, intermittent burial of tiles between collection trips could reduce the thickness or change the character of the coatings, and variations in the rate of periphyton growth on the tiles or abrasion of the coatings during high flows could also affect the concentrations. Despite the variability, however, the trend of the metal concentrations was upward with time.

Table 10.--Heavy-metal concentrations on ceramic tiles emplaced on bottom of the Saw Mill River.

[Analyses by U.S. Geological Survey. Concentrations in µg/cm^2 of tile surface. Site locations are shown in fig. 1.]

Site Number	Date collected	No. of days in place [1]	Cd	Cr	Co	Cu	Fe	Pb	Mn	Ni	Zn
320	06-02-82	42	4	4	<4	50	1,800	47	--	18	110
	07-19-82	89	7	--	14	--	2,700	110	14,000	61	430
	08-24-82	125	11	<4	25	54	3,100	120	16,000	61	540
	09-29-82	161	7	14	22	79	4,000	220	14,000	65	610
	11-09-82	202	4	11	25	68	4,300	210	13,000	61	580
	12-21-82	244	18	7	50	58	2,800	180	12,000	100	400
	02-01-83	286	4	4	54	220	5,000	260	19,000	83	680
410	06-02-82	42	4	--	11	54	1,900	54	11,000	25	220
	07-19-82	89	11	4	11	54	2,000	120	13,000	47	290
	08-24-82	125	18	<4	43	110	2,300	200	22,000	100	680
	09-29-82	161	7	11	32	68	3,200	300	30,000	120	970
	11-09-82	202	7	11	43	83	5,000	330	30,000	140	900
	12-21-82	244	7	4	76	86	4,300	470	40,000	210	1,100
	02-01-83	286	14	4	130	200	5,800	500	61,000	500	1,700
443	06-02-82	42	4	--	14	47	4,000	97	25,000	29	400
	07-19-82	89	4	14	32	58	4,900	160	56,000	61	340
	08-24-82	125	7	<4	36	65	3,600	130	40,000	61	360
	09-29-82	161	7	11	22	79	5,400	170	27,000	94	680
	11-09-82	202	<4	11	32	79	9,400	170	36,000	94	610
	12-21-82	244	7	4	50	79	6,500	120	36,000	160	540
	02-01-83	286	4	4	65	200	9,700	190	47,000	140	830
450	06-02-82	42	18	11	47	90	4,700	130	54,000	65	500
	07-19-82	89	11	14	61	100	6,100	240	65,000	160	950
	08-24-82	125	11	<4	40	110	4,000	220	47,000	130	1,100
	09-29-82	161	4	18	25	58	5,800	150	36,000	83	470
	11-09-82	202	<4	11	32	83	6,500	230	29,000	100	860
	12-21-82	244	10	<4	72	140	5,400	430	47,000	260	1,500
	02-01-83	286	7	7	83	270	9,000	290	65,000	500	2,300
470	06-23-82	63	11	4	72	180	5,800	220	79,000	160	1,000
	07-19-82	89	22	18	68	110	5,800	260	155,000	230	1,200
	08-24-82	125	25	7	61	190	6,100	360	137,000	310	1,700
	09-29-82	161	32	11	58	210	7,200	310	137,000	360	2,400
495 [2]	06-23-82	63	7	<4	65	290	8,300	170	36,000	110	1,330
	07-19-82	89	80	4	36	100	8,100	240	76,000	100	1,900
	11-09-82	41	<4	11	4	36	3,600	94	--	<4	140
	12-21-82	83	10	<4	43	86	7,200	140	13,000	27	610
	02-01-83	125	7	11	72	190	9,700	230	32,000	65	1,300
503	07-19-82	26	7	11	40	110	4,500	160	100,000	100	2,000
	08-24-82	62	29	7	76	330	11,000	650	140,000	310	4,000
	09-29-82	98	36	22	140	360	22,000	650	130,000	580	6,800
	11-09-82	139	50	18	280	610	40,000	1,200	400,000	680	11,000
	12-21-82	181	43	40	180	--	140,000	1,200	220,000	540	8,600
	02-01-83	223	36	--	190	540	150,000	1,300	280,000	650	9,700
Laboratory tiles	06-02-82	42	<4	--	<4	--	500	30	<36	20	72
	07-19-82	89	<4	--	10	20	180	20	72	4	36
	08-24-82	125	7	<4	10	30	470	10	36	7	72
	09-29-82	161	4	7	<4	20	320	30	<36	7	72
	11-09-82	202	<4	10	1	10	760	30	<36	<4	110
	12-21-82	244	4	<4	--	30	360	40	<36	20	72
	02-01-83	286	4	<4	4	10	250	25	<36	4	72

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[1] Tile sets were emplaced originally at all sites on 04-21-82. Tile sets were lost from sites 470, 495, and 503 during the study. Tiles were replaced at sites 495 and 503 on 09-29-82 and 06-23-82, respectively.

[2] First two sets of analyses represent original tile set; last three sets of analyses represent replacement tiles emplaced on 09-29-82.

Metal concentrations on tiles from the three lowermost sites (470, 495, and 503) were appreciably higher than on tiles that had been in place for a comparable period further upstream. (See table 10.) Plots of the metal concentrations in relation to river miles from sites 320 through 503 on two collection dates are shown in figure 6; site 495 is not included in these plots because the original tile set was lost early in the study. Iron and manganese concentrations on tiles from the lower sites were appreciably higher than on tiles from upstream sites, unlike the bottom sediment samples, which did not show downstream enrichment of iron and manganese. Chromium values at all sites but 503 were similar to those of the laboratory control tiles. Concentrations of all metals at site 443, which is immediately downstream from an impoundment, were low in relation to sites on either side. The setting of the site may be responsible for the lower concentrations, but no mechanism for the difference is offered.

The chemistry of the tile coatings must be interpreted with caution because few studies relating stream-water quality to heavy-metal deposition on artificial substrates have been done. Carpenter and Hayes (1978) found a correlation between quantity of heavy metals entering a stream and the concentrations of the metals deposited on ceramic tiles at specified distances downstream. Cerling and Turner (1982) found that coatings that formed on glass plates emplaced in a stream were related to the metal concentrations, the pH, and the oxidation potential of the water. Results of the above seem to support indications that higher heavy-metal concentrations on tiles at downstream sites reflect a downstream deterioration in water quality.

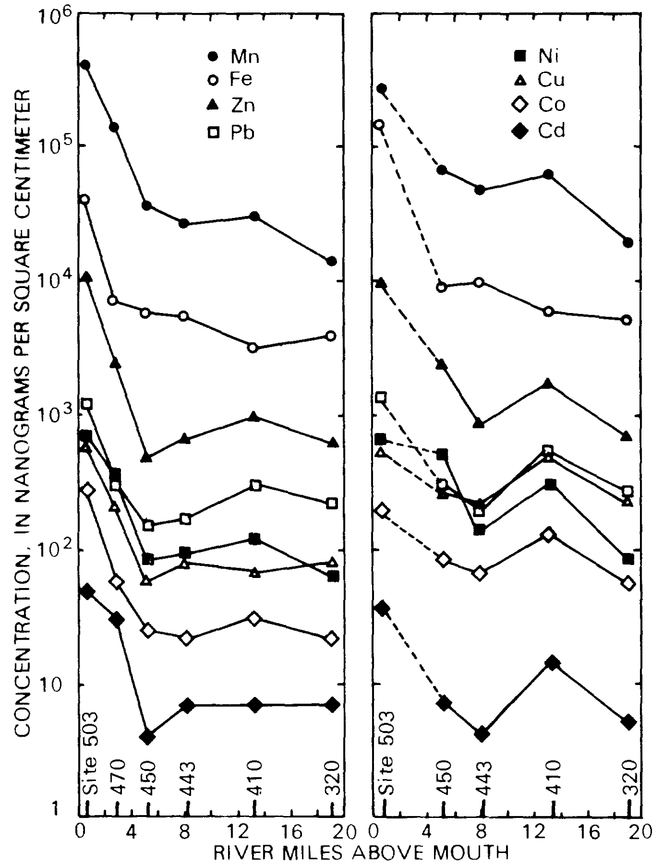

Figure 6.

Concentrations of heavy metals deposited on ceramic tiles emplaced in the Saw Mill River.

Organic Compounds

River water

Few organic compounds were detected in river-water samples. Volatile organic compounds were detected in all samples collected in February and August 1981, but none were detected in samples collected in August 1982. Results are given in table 11. The volatile organic compounds detected in this study were solvents used principally as metal cleaners, degreasers, and dry-cleaning agents. Volatile organic compounds are difficult to sample and analyze, and only a small number of samples were analyzed; thus the results reported herein should not necessarily be considered representative of the river.

Water samples collected in April and August 1982 at sites 320, 420, 460, and 503 were analyzed for acid- and base/neutral-extractable organic compounds and organochlorine and organophosphorous compounds. The only sample to contain any of these compounds above their analytical detection limits (tables 2 and 4) was the August sample from site 503, in which the total gross PCB concentration was 0.1 µg/L.

Table 11.--Concentrations of volatile organic compounds in the Saw Mill River, 1981-82.

[Analyses of the U.S. Geological Survey. N.D., none detected at minimum detection limit of 1.0 microgram per liter; see table 2 for a complete list of compounds on the analysis list. Site locations are shown in fig. 1.]

Site-identification number	Date	Compound(s) detected	Concentration (µg/L)
320	02-10-81	Tetrachloroethylene	2.0
	08-17-82	N.D.	--
420	08-17-82	N.D.	--
460	02-10-81	1,2-*trans*-Dichloroethylene	2.0
		Trichloroethylene	10.0
	08-12-81	1,2-*trans*-Dichloroethylene	8.0
		Trichloroethylene	20.0
	08-17-82	N.D.	--
495	08-12-81	1,2-*trans*-Dichloroethylene	8.0
		1,1,1-Trichloroethane	30.0
503	02-10-81	Trichloroethylene	2.0
	08-17-82	N.D.	--

Samples from 11 sites were collected in September 1981 and analyzed for total phenols. Eight of the sites (310, 320, 390, 410, 440, 443, 450, 460) showed concentrations below the analytical detection limit of 1 µg/L; the other three (sites 420, 495, and 503) had concentrations of 2, 4, and 1 µg/L, respectively. Total phenols include a variety of organic compounds, both natural and synthetic. Chlorinated phenols can cause odors in domestic water supplies; they may form when phenols entering a water-treatment plant are chlorinated in the final treatment process. To avoid odors, a water-quality criterion of 1 µg/L total phenols has been established by the U.S. Environmental Protection Agency (1977) for domestic water supplies.

Total cyanide was determined on two samples collected at sites 440 and 460 in August 1981; neither was above the detection limit of 0.01 µg/L.

Bottom Sediments

Concentrations of organochlorine compounds detected in whole bottom sediments are summarized in table 12; most of the compounds on the analysis list were not present above the analytical detection limits. (Compare tables 4 and 12). No organophosphorous compounds were detected.

Pesticides and PCB's.--The pesticide DDT and its metabolites DDD and DDE are present in bottom sediments throughout the basin and, as a group, follow no apparent spatial trend (fig. 7). DDD concentrations may be higher downstream of river mile 6.0, however (table 12). The pesticides chlordane and dieldrin are both present at all but the uppermost site and, as with DDT, they follow no apparent spatial trend. Chlordane was the most abundant pesticide in the river-bottom sediments. Heptachlor expoxide, a metabolite of the pesticide heptachlor, was detected at only one site.

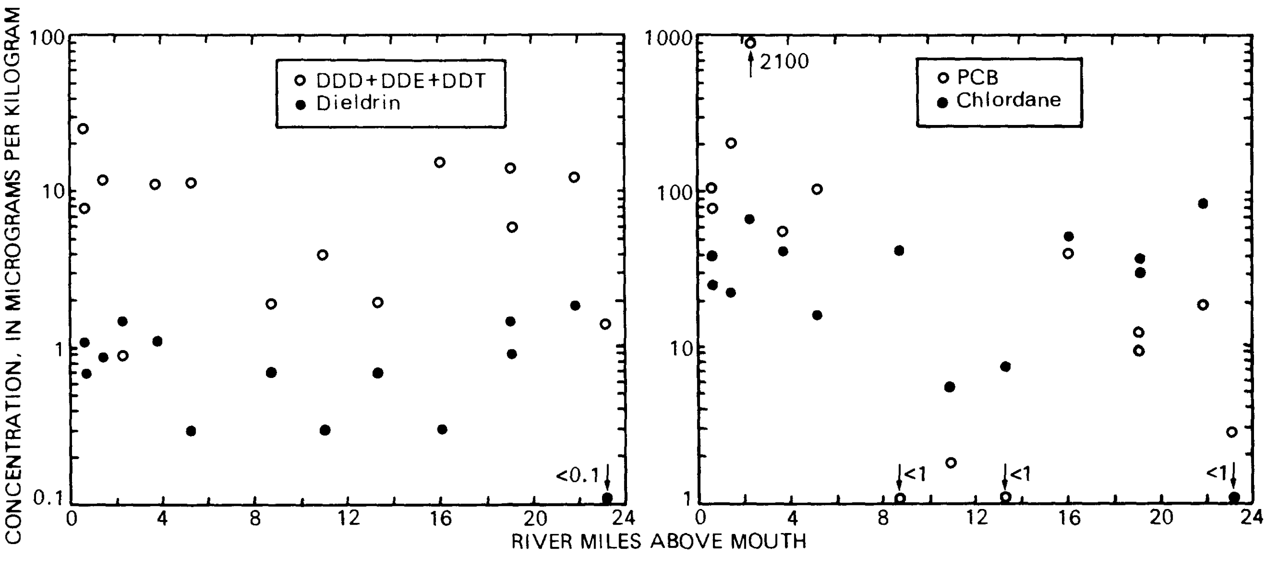

Figure 7.--Plots showing chlorinated hydrocarbon concentrations in bottom sediments in the Saw Mill River.
A. Dieldrin and DDD + DDE + DDT. B. Chlordane and PCB.

PCBs, unlike the pesticides, exhibit a pronounced trend. The six highest PCB concentrations, and the only concentrations above 50 µg/kg, were found below river mile 6.0. (See fig. 7.)

In 1976, bottom sediments from four sites on the Saw Mill River were analyzed by the U.S. Geological Survey for organochlorine compounds (Archer and Turk, 1977). The 1976 samples were collected at or near sites 415, 420, 460, and 495 of this study. Results of the 1976 analyses are listed in table 13.

Table 12.--Concentrations of organochlorinecompounds in bottom sediments from the Saw Mill River, 1981.

[Analyses by the Geological Survey. Concentrations in µg/kg; concentrations of organophosphorous and other organochlorine compounds were below minimum detection limits; see table 4 for a complete list of compounds on the analysis list. Site locations as shown in fig. 1.]

Site-identification number	Date	Concentrations						
		Chlordane	DDD	DDE	DDT	Dieldrin	Gross PCB	Heptachlor epoxide
308	11-17-81	<1.0	0.4	0.7	0.3	<0.1	3	<0.1
310	08-12-81	91	<.1	12	<.1	1.8	20	<.1
320	02-10-81	38	1.2	8.4	4.1	1.4	10	.4
	08-12-81	32	1.6	<.1	4.2	.9	13	<.1
390	09-02-81	55	2.2	5.6	8.2	.3	42	<.1
410	08-11-81	8.0	<.1	<.1	1.9	.7	<.1	<.1
420	08-11-81	6.0	2.0	.6	1.4	.3	19	<.1
440	08-12-81	43	<.1	<.1	1.9	.7	<.1	<.1
450	09-01-81	17	6.2	1.6	3.2	.3	110	<.1
460	08-12-81	44	9.2	.6	1.2	1.1	58	<.1
475	08-12-81	69	<.1	.9	<.1	1.5	2,100	<.1
495	08-12-81	23	9.2	<.1	2.6	.9	210	<.1
503	02-10-81	41	11	<.1	14	1.1	84	<.1
	08-12-81	27	6.9	<.1	1.1	.7	110	<.1

Because analyses of bottom sediments yield only semiquantitative results, it is impossible to compare data from 1976 to data from this study quantitatively. Also, the comparisons that can be made are limited by the small number of analyses from 1976. Several observations are noteworthy, however. First, all organochlorine compounds detected in 1976 were detected in this study, and vice versa. Second, the highest concentrations of organochlorine compounds in both 1976 and in this study 1981 were found at or downstream from site 460.

Table 13.--Concentrations of organochlorine compounds in bottom sediments from the Saw Mill River, 1976.

[Analyses by U.S. Geological Survey. Concentrations in µg/kg; source: Archer and Turk, 1977. Site locations are shown in fig. 1. Dashes indicate concentrations below detection limit.]

Site identification[1]	Date	Concentration						
		Chlordane	DDD	DDE	DDT	Dieldrin	Gross PCB	Heptachlor epoxide
415	08-31-76	11	1.4	--	1.3	--	--	--
420	08-31-76	10	2.7	0.7	3.5	0.7	38	0.1
460	08-31-76	55	12	--	--	--	42	--
495	08-31-76	99	24	--	18	--	720	--
	11-17-76	110	41	7.6	23	5.7	1,300	--

[1] Sites identified by number of the closest site in this study.

Acid- and base/neutral-extractable compounds.--Concentrations of acid- and base/neutral-extractable organic compounds detected in bottom sediments are listed in table 14. Concentrations of organic compounds in bottom sediments are dependent on the matrix composition of the sediment and do not simply reflect the concentration or quantity of the compound in the water column that has passed over the sediment. In general, as the organic carbon content of sediment increases, so does its ability to sorb organic contaminants (Goerlitz and Law, 1974; Means and others, 1980). Variations in sediment composition complicate comparisons among the samples, but several general observations can be made.

Table 14.--Concentrations of acid-
in bottom sediments from

[Analyses by U.S. Geological Survey. Concentration in μg/kg.
Dashes indicate not detected; detection limits are dependent
An approximate detection limit of 20 μg/kg has been established

Site no.	Date collected	Acenaphthene	Acenaphthylene	Anthracene/ Phenanthrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(g,h,i)perylene	Benzo(a)pyrene	Chrysene
320	08-12-81[1]	--	--	1,900	--	--	--	--	--	--
	08-24-82	--	--	1,440	810	1,400	--	--	830	640
410	08-24-82	--	--	--	--	--	--	--	--	--
420	08-11-81[1]	--	--	200	--	--	--	--	--	--
	08-24-82	--	--	1,100	--	370	--	--	570	3,900
450	08-24-82	--	--	360	350	--	220	340	--	290
460	08-11-81	--	--	65	--	--	--	--	--	--
	08-24-82	--	--	--	--	--	--	--	--	--
470	08-24-82	--	--	3,130	700	820	--	--	1,100	420
495	08-12-81	--	--	170	--	--	--	--	--	--
	08-24-82	13,000	680	6,800	1,400	1,700	--	320	860	1,600
503	08-12-81[1]	--	--	490	--	--	--	--	--	--
	08-24-82	--	1,800	1,190	280	290	--	97	290	170

[1] Gas-chromatograph/mass-spectrometer scans, not full analyses.

and base/neutral-extractbale compounds
the Saw Mill River, 1981-32.

Site locations are shown in fig. 1.
on the matrix composition of the sediment and are variable.
by the laboratory; ND indicates not determined.]

Site no.	Dibenzo(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Pyrene	Butyl benzyl phthalate	Di-n-butyl phthalate	Di-n-octyl phthalate	Bis(2-ethylhexyl)phthalate	n-Nitrosodiphenylamine	4-Nitrophenol
320	--	1,300	240	--	--	1,200	--	--	--	--	--	ND
	--	1,100	--	--	--	1,000	--	260	--	2,200	--	--
410	--	--	--	--	--	--	--	--	--	--	--	--
420	--	160	--	--	--	230	--	--	--	--	--	ND
	520	1,100	--	--	--	1,200	--	340	--	1,400	--	--
450	--	860	--	45	--	850	--	--	--	--	--	--
460	8	20	--	--	--	110	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--	--
470	--	590	--	--	--	1,200	--	380	--	2,400	--	--
495	--	165	--	--	--	210	--	--	--	--	--	--
	--	6,000	1,200	270	1,200	5,000	950	420	610	740	--	4,200
503	--	280	21	--	--	320	--	--	--	--	--	ND
	--	350	--	100	--	600	--	--	--	190	1,400	--

Of the 57 compounds on the analysis list (table 2), 22 were detected in the Saw Mill River sediments. Only one acid-extractable compound, 4-nitrophenol, was detected, and it was detected at only one site (site 495). Of the 21 base/neutral-extractable compounds detected, six were at only one site, and four of the six were at site 495. Six compounds were detected at five or more sites; all were polynuclear aromatic hydrocarbons.

Of the 22 compounds detected in the river, 19 were at site 495 and 14 at site 503. The highest concentrations of 16 compounds were also found at either site 495 or 503. The high concentrations of organic compounds in the 1982 sample from site 495 (table 14) may be explained in part by a high sorptive capacity of the sediment as a result of its high organic carbon concentration. The organic carbon concentration of 1,000- to 2,000-µm sediment collected at the same time as the sediment sample for organic compounds was 100 µg/kg, much higher than at the other sites (table 17). (The 1981 sample from site 495 was collected soon after completion of the concrete channel and may not have been fully representative of the site at later sampling times.) The higher concentrations found at site 503, however, cannot be attributed to abnormally high concentrations of organic carbon.

The only site at which none of the acid- or base/neutral-extractables were detected was site 410. The low organic carbon concentrations in sediment at that site (table 17) may be partly responsible.

The largest group of base/neutral-extractable compounds detected in the bottom sediments was polynuclear aromatic hydrocarbons (PAH's). PAH's form a diverse group of chemical compounds that are widely distributed in the environment. They occur in fossil fuels and are common combustion products of carbon-based materials such as gasoline and diesel fuel.

Phthalate esters were detected in bottom sediments from five sites (table 14). Phthalate esters, which are used in the manufacturing of plastics, are ubiquitous, and samples are often subject to contamination by these compounds during collection and in the laboratory. Because "background" levels of phthalate esters in the environment are not known, and because relatively few values are available from this study, it is not possible to determine the severity of phthalate contamination in the Saw Mill River or if it even exists.

Total cyanide.--The following bottom-sediment size fractions, collected in August 1981, were analyzed for total cyanide: 1,000- to 2,000-µm sediment from 13 sites, five finer sediment fractions from sites 460 and 495, and whole sediment from sites 460 and 495. All values were below the detection limit of 0.5 mg/kg.

RELATION OF RIVER QUALITY TO URBANIZATION

Nonpoint sources of contaminants can significantly affect river quality. Runoff from urban areas can be especially detrimental, and runoff from industrialized areas contributes greater quantities of nutrients, heavy metals, and organic contaminants to rivers than runoff from other types of urban areas, such as residential tracts (Browne and Grizzard, 1979; Wilber and Hunter, 1979a; Hunter and others, 1979).

The Saw Mill River basin is mostly urban, but land use differs from one end of the basin to the other. In the downstream section of the basin, between the City of Yonkers water-treatment plant at river mile 3.7 and the lowest sampling site at river mile 0.6, 13.7 percent of the basin is classified as manufacturing/industry/warehouse; in the remainder of the basin, upstream from the water-treatment plant, only 2.3 percent of the basin is so classified. Most of the industries in the basin are close to the river. Only 1.8 percent of the basin downstream of river mile 3.7 is undeveloped, whereas 17.1 percent of the basin upstream from that point is developed. The residential areas downstream of river mile 3.7 are medium to high density; those upstream of mile 3.7 are medium to low density. Virtually all parks, cemeteries, and other open spaces are above river mile 3.7. In accordance with this pattern, the lower part of the basin has a higher percentage of impervious area and thus a higher runoff-to-rainfall ratio than the upper part.

<u>Orthophosphate</u>.--The water chemistry and bottom-sediment chemistry of the Saw Mill River reflect the land-use distribution within the basin. The highest concentrations of dissolved orthophosphate were found at site 460 and below, the area of greatest urban development. Whipple and others (1978) reported that urbanization can markedly increase nonpoint orthophosphate loads in rivers; data summarized by Browne and Grizzard (1979) support this observation.

<u>Heavy metals</u>.--The heavy-metal data gathered in this study point to a deterioration in river quality in the lower part of the basin that is directly attributable to urbanization and industrialization. Typical sources and uses of heavy metals investigated in this study are listed in table 15; geologic sources are not included.

In an investigation of the relationship between heavy metals and land use in a section of the Saddle River basin around the industrialized borough of Lodi, in northern New Jersey, Wilber and Hunter (1975, 1979a, 1979b) found that heavy-metal concentrations in river-bottom sediments increased with urbanization. In comparing street sweepings from industrial and residential users in Lodi, Wilber and Hunter (1979b) found that concentrations of zinc, copper, nickel, chromium, manganese, and iron in the industrialized area were higher than those in the residential area and at a traffic intersection. Street sweepings are analogous to the soils analyzed in this study in that both serve as medium for the transport of heavy metals into the river, especially during times of stormwater runoff. Soils from the lower part of the Saw Mill River basin contained higher concentrations of copper, lead, and zinc than soils from the upper part of the basin, and soils subject to runoff from paved surfaces contained higher concentrations of copper, lead, and zinc than the other soils.

The heavy-metal chemistry of the tile coatings and of the river water collected during this study strengthens the correlation between deteriorating water quality and urbanization. Tiles emplaced downstream of river mile 3.0, the most heavily developed reach of the river, contained the higher concentrations of cadmium, cobalt, copper, iron, lead, manganese, nickel, and zinc than the tiles emplaced upstream. Likewise, the highest concentrations of arsenic, cadmium, copper, lead, and zinc in the river water were recorded downstream of river mile 4.0.

The heavy-metal data do not suggest a single point source of metals in the downstream reaches of the river; rather, they suggest multiple, closely spaced sources, a consequence of urban development, as the cause of the higher concentrations.

Organic compounds.--Bottom-sediment analyses for organic contaminants are more difficult to interpret than those for metals because the sorption of organic contaminants and the analytical ability to measure the contaminants are a function of the sediment composition. In addition, fewer sediment samples were analyzed for organic contaminants than for heavy metals; thus, trends in organic contaminants along the river, if present, may be difficult to detect and define at present. Some correlations between organic contaminants and land use are discernible from the data, however, as follows.

Table 15.--Uses of selected heavy metals.

Metal	Use or source
Cadmium	Batteries, electroplating, chemical industry, tires, pigments, heating oils, motor oils, coal, plastics, photography.
Chromium	Alloys, refractories, electroplating, tanning industry, pigments, bactericides, glass, paper mills, photography.
Cobalt	Alloys, glass, pottery, ink, pigments, chemical industry.
Copper	Electroplating, ink, dyes, pigments, alloys, tanning industry, pharmaceuticals, textile industry, chemical industry.
Lead	Automobile exhaust, batteries, textile industry, pigments, photography.
Nickel	Alloys, electroplating, catalyst, ceramics, storage batteries, glass.
Zinc	Alloys, electroplating, tanning industry, paints, tires, plastics, ink, batteries, fluorescent lights, chemical industry, pharmaceuticals.

Bottom-sediment analyses indicate that greater amounts of PCB's are entering the river in the downstream, more industrialized, section of the basin than in the upstream section. The single water sample in which PCB's were detected came from the lowest sampling site, which supports this observation.

The greatest number of PAH's were detected in bottom sediments from the two sampling sites farthest downstream, and in general, the highest concentrations of the various compounds were at site 495. Again, the data suggest a correlation between higher contaminant concentrations and greater urban development. Daisey and others (1979) found automobile exhaust to be the greatest source of airborne PAH's in New York City; similar results were obtained in a study of PAH's in Los Angeles (Gordon, 1976). Because automobile traffic is heaviest in the lower part of the basin, the amounts of PAH's produced there is correspondingly high. Further, the high percentage of impervious area in the lower basin allows PAH aerosols that settle to land surface to be more easily washed into the river than in upstream areas of the basin, where soil cover is more extensive. Herrmann (1981) found that PAH's are adsorbed by street dust and consequently washed into urban rivers. Wakeham and others (1980) have suggested that asphalt particles that are carried into rivers by runoff are a source of PAH's in heavily developed areas.

In conclusion, the orthophosphate, heavy-metal, PCB, and PAH data all indicate that the chemical quality of the Saw Mill River deteriorates over the lower 3 to 4 miles. Recorded discharges of these substances do not account for the deterioration. Only three permits that allow industrial discharges into the Saw Mill River have been issued by the State of New York; one allows low concentrations of oil and grease (15 mg/L) to enter the river below river mile 3.0, and the other two allow cooling water to be discharged to the river. Because the concentrations of not just one constituent but of several follow a similar trend, and because the area of highest concentrations corresponds to the area of greatest urban development, the deterioration in water quality is probably a consequence of urban runoff. In urban areas, a large percentage of contaminants attributed to nonpoint sources may actually originate from storm sewers and unrecorded point sources (Whipple and others, 1978). The occasional occurrence of untreated domestic sewage in the lowest few miles of the river indicates that unrecorded point sources are partly responsible for the deterioration in chemical quality of the lower part of the Saw Mill River.

SUMMARY

This report presents the results of a 3-year study of the chemical quality of the Saw Mill River in Westchester County. The river is 23.5 mi long and drains a narrow 26.5-mi^2 basin that is primarily urban. Development is heaviest along the lower 4 miles of the river. The purpose of the study was to determine what contaminants are present in the river, determine their concentration and distribution and, if possible, determine whether the contaminants are contributed by point or nonpoint sources.

The sampling program, which extended from February 1981 through February 1983, emphasized river-bottom sediments because they sorb many types of contaminants from the water column. Water and soil samples were also taken.

Both water and bottom-sediment samples were analyzed for heavy metals, major nutrients, and synthetic organic compounds, most of which are on the USEPA "priority pollutant" list. Several sets of ceramic tiles were emplaced in the river for study of heavy metals in the coatings that formed.

Bottom sediments were collected at 20 sites (three on tributaries), water samples at 11 sites, and soil samples at 10 sites. The ceramic tiles were emplaced and sampled at seven sites. Bottom sediments from six sites were separated into six size fractions to investigate the relationship between sediment size and the concentration of nutrients and heavy metals.

Nutrients.--Dissolved forms of organic carbon and nitrogen predominated over suspended forms in the water column. About half the phosphorus in the water column was associated with suspended sediment. None of the water samples contained nitrite, nitrate, or un-ionized ammonia in concentrations exceeding USEPA water-quality criteria or New York State Department of Health standards for sources of water supplies. Dissolved-orthophosphate concentrations were highest in the downstream third of the river. Other nutrients exhibited no trend.

Concentrations of phosphorus, organic carbon, and organic and total nitrogen in bottom sediments vary as a function of grain size. Concentrations were greater in the 1,000- to 2,000-µm sediment than in the 250- to 1,000-µm sediment, while the highest concentrations were in sediment fractions less than 250 µm. Concentrations of nitrogen, phosphorus, and organic carbon in whole bottom sediments (<2,000 µm) and 1,000- to 2,000-µm sediment were variable along the river, and no spatial trend was apparent.

Heavy metals.--Dissolved manganese was the only heavy metal to regularly exceed criteria established by the USEPA for domestic water supplies. None of the heavy metals exceeded standards for sources of water supplies established by the New York State Department of Health. Collectively, the water analyses for heavy metals indicate that water quality deteriorates downstream. The highest concentrations of copper, lead, zinc, cadmium, and arsenic were found at sites in the lowest 4 miles of the river.

Heavy-metal concentrations in sediments, like nutrient concentrations, vary as a function of grain size. Concentrations are highest in the <63-µm sediment and decrease with increasing grain size into the 500- to 1,000-µm. Thereafter the concentrations again increase, giving the 1,000- to 2,000-µm sediment, the coarsest fraction analyzed, higher heavy-metal concentrations than intermediate size fractions.

Spatial variations in heavy-metal concentrations were investigated in the 1,000- to 2,000-µm sediment fraction. Bottom sediment in the lowest 3 miles of the river was found to be significantly enriched with copper, lead, and zinc. The mean concentrations of these metals in the downstream sediment were 4.0, 3.8, and 3.9 times higher, respectively, than the means for the upstream sediment. Iron and manganese exhibited no trend, nor did arsenic, cobalt, mercury, or nickel, all of which were near or less than their respective analytical detection limits.

Heavy-metal concentrations in the soils paralleled those of the sediments. Copper, lead, and zinc concentrations were highest in soils from the lower basin; iron and manganese in the soils showed no spatial trend.

Manganese was by far the most abundant metal deposited on the ceramic tiles. The concentrations of all metals investigated--cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, and zinc--were highest on tiles from the three sites downstream of river mile 3.0. The tile data form additional evidence of higher concentrations of heavy metals and, consequently, poorer water quality in the downstream reach of the river.

Organic compounds.--Few organic compounds were detected in water samples collected during this study. Tetrachloroethylene, 1,2-*trans*-dichloroethylene, trichloroethylene, and 1,1,1,-trichloroethane, all volatile compounds, were detected; concentrations ranged from 2 to 30 µg/L. None of the compounds were found at all sites, nor did they persist at individual sites during the study. The only organochlorine compound detected in river water was PCB, which was detected in only one sample. None of the organophosphorous, acid-extractable, or base/neutral-extractable compounds on the analysis list were detected in the river water. Total phenols were found in waters at three of 11 sites sampled; the highest concentration was 4 µg/L at river mile 1.5.

Chlordane, DDD, DDE, DDT, dieldrin, and PCB's were found in bottom sediments along the entire river. The six highest PCB concentrations occurred in the lowest 6 miles of the river. None of the other compounds exhibited spatial trends. Of the 57 acid- and base/neutral-extractable compounds on the USEPA "priority pollutant" list, 22 were detected in bottom sediments. None was found at all sampling sites. Of the 22 compounds, 16 were polynuclear aromatic hydrocarbons, and four were phthalate esters. The greatest variety of compounds found was at the two lowermost sites, downstream of river mile 2.0.

General trends.--Urban development is greatest in the lowest part of the Saw Mill River drainage basin, which is within the City of Yonkers. The percentage of land downstream from the City of Yonkers water-treatment plant that is used by industry is about six times greater than the percentage of land so used upstream from the plant, which is 3.7 miles from the river mouth.

The distributions of orthophosphate, heavy metals, PCB's, and polynuclear aromatic hydrocarbons all indicate that the chemical quality of the Saw Mill River deteriorates downstream over the lowest 4 river miles. The coincidence of the higher concentrations of a variety of contaminants within the area of greatest urban development indicates urban runoff to be the major cause of the downstream deterioration in river quality.

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TABLES 16, 17, 18

Page

Table 16.--Concentrations of nitrogen, phosphorus, and carbon in water from the Saw Mill River, 1981-82. . . . 44

Table 17.--Concentrations of nitrogen, phosphorus, and carbon in bottom sediments from the Saw Mill River, 1981-82. . . . 46

Table 18.--Concentrations of heavy metals in waters from the Saw Mill River, 1981-82. . . . 50

Table 16.--Concentrations of nitrogen, phosphorus, and carbon in water from the Saw Mill River, 1981-82.

[Analyses by U.S. Geological Survey. Site locations are shown in fig. 1, a dash indicates no analysis.]

Date	Time	Nitrogen dissolved (mg/L as N)	Nitrogen, total (mg/L as N)	Nitrogen, organic dissolved (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, nitrate total (mg/L as N)
310 - SAW MILL RIVER AT CHAPPAQUA											
5-12-81	0845	1.2	1.3	0.61	0.68	0.07	0.07	0.01	0.02	0.54	0.53
320 - SAW MILL RIVER AT PLEASANTVILLE											
2-10-81	1620	2.1	2.2	.38	.51	--	--	.02	.03	1.6	1.6
4-21-82	1550	2.2	2.2	1.1	1.1	.06	.05	.04	.01	.96	1.1
420 - SAW MILL RIVER AT ELMSFORD											
4-21-82	1440	--	2.2	--	1.1	.04	.05	.01	.02	1.1	1.1
440 - SAW MILL RIVER AT WORTHINGTON											
8-12-81	1345	1.1	1.1	.41	.42	.03	.02	.03	.03	.62	.63
450 - SAW MILL RIVER AT MOUNT HOPE											
5-11-81	1400	1.0	1.3	.37	.69	.12	.10	.03	.03	.52	.51
460 - SAW MILL RIVER AT GREY OAKS AT YONKERS											
2-10-81	1400	1.9	1.9	.56	.52	.07	.08	.04	.04	1.30	1.3
8-12-81	1145	1.1	1.5	.30	.72	.08	.06	.02	.02	.66	.66
4-21-82	1240	1.2	1.1	.33	.21	.03	.03	.01	.01	.85	.89
495 - SAW MILL RIVER AT ASHBURTON AVE AT YONKERS											
5-11-81	1100	1.2	2.3	.60	1.4	.04	.31	.05	.06	.48	.58
503 - SAW MILL RIVER AT ELM ST AT YONKERS											
2-10-81	1200	2.6	3.0	.96	1.4	.44	.45	.05	.05	1.2	1.2
4-21-82	1020	2.6	2.9	1.5	1.8	.14	.11	.02	.02	.96	.98

Date	Nitrogen, ammonia + organic dis. (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, NO2+NO3 dissolved (mg/L as N)	Nitrogen, NO2+NO3 total (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Carbon, organic dissolved (mg/L as C)	Carbon, organic total (mg/L as C)	Carbon, inorganic, dissolved (mg/L as C)	Carbon, inorganic, total (mg/L as C)
310 - SAW MILL RIVER AT CHAPPAQUA											
5-12-81	0.68	0.75	0.55	0.55	0.02	0.12	0.02	7.1	8.6	9.9	14
320 - SAW MILL RIVER AT PLEASANTVILLE											
2-10-81	.50	.55	1.6	1.6	.06	.10	.02	6.0	6.6	18	21
4-21-82	1.2	1.10	1.0	1.1	.04	.02	<.01	3.5	3.2	11	16
420 - SAW MILL RIVER AT ELMSFORD											
4-21-82	--	1.10	1.1	1.1	.02	.06	.01	3.7	3.5	21	23
440 - SAW MILL RIVER AT WORTHINGTON											
8-12-81	.44	.44	.65	.66	.04	.11	.04	4.3	7.4	34	37
450 - SAW MILL RIVER AT MOUNT HOPE											
5-11-81	.49	.79	.55	.54	.05	.07	.03	2.7	4.5	28	34
460 - SAW MILL RIVER AT GREY OAKS AT YONKERS											
2-10-81	.63	.60	1.3	1.3	.09	.15	.04	4.7	6.3	18	18
8-12-81	.38	.78	.68	.68	.05	.14	.06	1.6	5.1	39	34
4-21-82	.36	.24	.86	.90	.01	.04	<.01	2.8	2.6	28	25
495 - SAW MILL RIVER AT ASHBURTON AVE AT YONKERS											
5-11-81	.64	1.70	.53	.64	.07	.40	.05	--	--	--	--
503 - SAW MILL RIVER AT ELM ST AT YONKERS											
2-10-81	1.4	1.80	1.2	1.2	.22	.22	.10	4.2	11	17	22
4-21-82	1.6	1.90	.98	1.0	.03	.11	.03	3.9	5.1	25	24

Table 17.--Concentrations of nitrogen, phosphorus, and carbon in bottom sediments from the Saw Mill River, 1981-82.

[Analyses by U.S. Geological Survey. Site locations shown in fig. 1, a dash indicates no analysis.]

Date	Size fraction (µm)	Nitrogen (mg/kg as N)				Phosphorus (mg/kg as P)	Carbon (g/kg as C)	
		Total	NH_4	NH_4+Organic	NO_2+NO_3		Inorganic	Organic
				310 - SAW MILL RIVER AT CHAPPAQUA				
5-12-81	<2,000	1960	6.1	1950	5.4	320	0.1	4.7
5-12-81	1,000-2,000	4600	5.1	4590	6.6	490	.6	11
5-12-81	500-1,000	519	2.8	517	1.9	260	.1	2.2
5-12-81	250-500	367	2.5	365	1.7	320	.1	7.1
5-12-81	125-250	9740	19	9730	11	830	.2	20
5-12-81	63-125	1070	6.8	1070	4.6	960	--	--
5-12-81	<63	7750	9.5	7740	6.4	1100	.0	43
8-12-81	<2,000	583	5.5	580	3.3	87	.8	47
				313 - TERCIA BROOK AT CHAPPAQUA				
8-12-81	<2,000	771	12	769	1.7	630	--	--
				320 - SAW MILL RIVER AT PLEASANTVILLE				
2-10-81	<2,000	632	10	630	1.9	360	8.7	6.3
2-10-81	1,000-2,000	446	108	440	6.4	350	30	7.0
2-10-81	500-1,000	504	9.4	500	4.1	390	32	4.0
2-10-81	250-500	535	28	530	4.9	510	20	4.0
2-10-81	125-250	755	25	750	5.0	570	11	7.0
2-10-81	63-125	3510	57	3500	12	840	8.8	16
2-10-81	<63	11100	94	11000	49	870	5.5	38
5-11-81	1,000-2,000	633	3.6	553	80	480	15	10
8-24-82	1,000-2,000		--	--	--	--	17	4.0
				330 - SAW MILL RIVER AT THORNWOOD				
8-11-81	<2,000	562	5.5	561	1.4	280	--	--

370 - NANNY HAGEN BROOK AT THORNWOOD								
8-11-81	1,000-2,000	453	8.6	449	4.2	170	--	--
390 - SAW MILL RIVER AT HAWTHORNE								
5-11-81	1,000-2,000	353	3.2	351	2.4	340	5.5	4.1
410 - SAW MILL RIVER AT EASTVIEW								
5-11-81	1,000-2,000	1270	2.9	1270	2.0	770	4.3	4.3
8-24-82	1,000-2,000		--	--	--	--	5.9	1.1
415 - SAW MILL RIVER NEAR ELMSFORD								
8-11-81	<2,000	1880	15	1880	2.4	210	--	--
417 - MINE BROOK AT ELMSFORD								
8-11-81	<2,000	508	6.8	499	9.2	200	--	--
420 - SAW MILL RIVER AT ELMSFORD								
5-11-81	1,000-2,000	568	9.0	565	3.1	470	4.0	12
440 - SAW MILL RIVER AT WORTHINGTON								
5-11-81	1,000-2,000	51	4.4	48	3.1	220	1.8	3.1
8-12-81	<2,000	512	11	510	1.5	430	--	--

Table 17.--*Concentrations of nitrogen, phosphorus, and carbon in bottom sediments from the Saw Mill River, 1981-82 (continued)*

Date	Size fraction (μm)	Nitrogen (mg/kg as N)				Phosphorus	Carbon (g/kg as C)	
		Total	NH_4	NH_4+Organic	NO_2+NO_3	(mg/kg as P)	Inorganic	Organic
			443 - SAW MILL RIVER AT WOODLANDS					
8-24-82	1,000-2,000	--	--	--	--	--	3.0	12
			450 - SAW MILL RIVER AT MOUNT HOPE					
5-11-81	<2,000	365	5.6	363	1.9	330	2.8	3.5
5-11-81	1,000-2,000	1020	5.8	1020	2.8	360	1.8	9.2
5-11-81	500-1,000	376	11	374	2.2	240	2.7	3.6
5-11-81	250-500	347	2.4	345	2.4	250	3.0	2.2
5-11-81	125-250	476	3.2	470	5.9	810	1.8	2.8
5-11-81	63-125	2680	42	2620	58	1100	2.4	13
5-11-81	<63	27800	63	27800	16	1200	--	--
			460 - SAW MILL RIVER AT GREY OAKS AT YONKERS					
2-10-81	<2,000	1920	35	1900	21	480	2.1	28
8-12-81	<2,000	1050	11	1050	2.9	360	.3	7.8
8-12-81	500-1,000	70	5.1	68	1.9	170	.4	6.7
8-12-81	250-500	43	10	41	1.5	66	.4	2.1
8-12-81	<63	9770	37	9760	5.8	900	1.0	24
			470 - SAW MILL RIVER AT OLD NEPPERHAN RD AT YONKERS					
8-12-81	<2,000	785	6.0	780	4.7	340	--	--
8-24-82	1,000-2,000	--	--	--	--	--	4.8	8.2

475 - SAW MILL RIVER AT WORTH ST AT YONKERS

5-11-81	1,000-2,000	715	3.3	713	2.0	270	4.4	16
8-12-81	<2,000	480	8.1	478	2.3	240	--	--

495 - SAW MILL RIVER AT ASHBURTON AVE AT YONKERS

5-11-81	1,000-2,000	305	5.4	296	8.5	580	3.5	136
5-11-81	500-1,000	211	3.4	208	3.4	350	1.2	2.9
8-12-81	<2,000	495	8.7	490	4.6	400	2.5	11
8-12-81	1,000-2,000	624	19	621	2.8	400	2.6	23
8-12-81	500-1,000	523	5.8	520	3.3	340	3.2	8.8
8-12-81	250-500	265	4.0	258	6.8	42	3.3	68
4-24-82	1,000-2,000	--	--	--	--	--	6.4	3.6
8-24-82	1,000-2,000	--	--	--	--	--	10	100

501 - SAW MILL RIVER OFF WALSH RD AT YONKERS

8-12-81	<2,000	409	4.5	405	3.7	310	--	--

503 - SAW MILL RIVER AT ELM AT YONKERS

2-10-81	<2,000	753	--	750	2.6	550	2.8	12
2-10-81	1,000-2,000	914	25	910	4.0	460	2.8	15
2-10-81	500-1,000	446	31	440	5.6	380	2.3	7.1
2-10-81	250-500	813	34	810	3.2	530	2.4	9.6
2-10-81	125-250	925	39	920	5.0	480	2.1	15
2-10-81	63-125	998	50	980	18	860	3.3	18
2-10-81	<63	5410	80	5400	8.0	1300	3.4	28
5-11-81	1,000-2,000	384	3.1	379	5.1	340	3.1	2.7
8-24-82	1,000-2,000	--	--	--	--	--	5.1	4.4

Table 18.--Concentrations of heavy metals in waters from the Saw Mill River, 1981-82.

[Analysis by U.S. Geological Survey. Site locations shown in fig. 1, a dash indicates no analysis.]

Date	Time	Temperature (Deg C)	Specific conductance (µmhos)	pH (units)	Concentrations (µg/L)							
					Arsenic		Cadmium		Chromium		Copper	
					Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
310 - SAW MILL RIVER AT CHAPPAQUA												
5-12-81	0845	14.0	160	7.0	<1	<1	<1	1	10	10	4	5
320 - SAW MILL RIVER AT PLEASANTVILLE												
2-10-81	1620	1.0	410	7.6	<1	<1	<1	<1	10	20	2	13
4-21-82	1550	14.5	360	8.3	--	--	<1	<1	10	20	4	17
8-17-82	1420	21.5	510	8.6	--	--	<1	1	10	10	5	10
420 - SAW MILL RIVER AT ELMSFORD												
4-21-82	1440	13.5	520	8.0	--	--	--	<1	10	20	--	16
8-17-82	1330	22.0	560	8.2	--	--	<1	1	10	10	9	7
440 - SAW MILL RIVER AT WORTHINGTON												
8-12-81	1345	24.5	420	7.1	--	--	2	1	20	30	3	8
450 - SAW MILL RIVER AT MOUNT HOPE												
5-11-81	1400	15.0	465	7.5	<1	<1	<1	1	<10	10	3	4
460 - SAW MILL RIVER AT GREY OAKS AT YONKERS												
2-10-81	1400	.5	760	7.6	<1	<1	<1	1	10	20	6	12
8-12-81	1145	24.0	570	7.1	--	--	<1	2	10	10	6	7
4-21-82	1240	13.5	525	8.1	--	--	<1	<1	10	20	4	12
8-17-82	1210	22.5	585	8.0	--	--	<1	1	<10	10	4	7
495 - SAW MILL RIVER AT ASHBURTON AVE AT YONKERS												
5-11-81	1100	15.0	410	7.4	1	<1	<1	2	10	20	18	45
503 - SAW MILL RIVER AT ELM ST AT YONKERS												
2-10-81	1200	.5	700	7.4	<1	1	<1	1	10	20	9	34
4-21-82	1020	13.0	595	8.0	--	--	--	<1	10	20	--	20
8-17-82	1100	23.0	580	8.6	--	--	<1	2	10	10	10	13

Date	Concentrations (µg/L)									
	Iron		Lead		Manganese		Mercury		Zinc	
	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
310 - SAW MILL RIVER AT CHAPPAQUA										
5-12-81	210	1100	1	4	70	130	--	<.1	4	10
320 - SAW MILL RIVER AT PLEASANTVILLE										
2-10-81	110	1600	3	13	80	120	.1	.1	<4	40
4-21-82	82	350	2	6	42	40	--	--	--	--
8-17-82	39	220	<1	5	5	30	--	--	<4	60
420 - SAW MILL RIVER AT ELMSFORD										
4-21-82	--	1000	--	13	--	100	--	--	--	--
8-17-82	33	360	1	5	83	130	--	--	<4	80
440 - SAW MILL RIVER AT WORTHINGTON										
8-12-81	100	610	1	12	60	220	--	--	<4	30
450 - SAW MILL RIVER AT MOUNT HOPE										
5-11-81	90	790	<1	6	140	200	--	<.1	5	10
460 - SAW MILL RIVER AT GREY OAKS AT YONKERS										
2-10-81	70	1300	3	22	80	80	<.1	.1	10	30
8-12-81	50	950	2	19	50	170	--	<.1	<4	40
4-21-82	60	600	<1	6	91	130	--	--	--	--
8-17-82	13	740	1	4	8	150	--	--	<4	100
495 - SAW MILL RIVER AT ASHBURTON AVE AT YONKERS										
5-11-81	230	2400	14	91	180	380	--	<.1	30	110
503 - SAW MILL RIVER AT ELM ST AT YONKERS										
2-10-81	60	1400	6	27	80	130	.1	.1	20	130
4-21-82	--	560	--	6	--	120	--	--	--	--
8-17-82	24	450	<1	6	2	90	--	--	<4	80