Water-Quality Characteristics of New Jersey Streams

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1819-G

Prepared in cooperation with the New Jersey Departments of Health, of Conservation and Economic Development, and of Agriculture

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By PETER W. ANDERSON *and* JOHN R. GEORGE

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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ABSTRACT

This report is based on a statewide reconnaissance of water-quality information performed as part of a long-range cooperative program between the State of New Jersey and the U.S. Geological Survey. A brief description of the relations between water quality and environment and a discussion of the areal and time variations of several water-quality parameters are presented.

The principal factors influencing stream quality are: differences in the quality of the individual components of streamflow, areal variations in geology, manmade changes in the natural stream regimen, and tidal invasion of salt water.

Normally the concentration of most chemical constituents and streamflow are related inversely, and thus concentration reflects the dilution effect of the flow. However, most streams in the southern part of the State exhibit a direct relation.

About 60 percent of New Jersey's area is drained by streams which are predominant in calcium and magnesium ions. The remainder is drained by sodium-potassium-type streams.

Streams draining the Valley and Ridge province and the New England Upland section are predominant in calcium, magnesium, and bicarbonate ions; the Piedmont Lowland section and inner Coastal Plain, in calcium, magnesium, and sulfate; and the outer Coastal Plain, in sodium, potassium, sulfate, and chloride.

Those streams draining highly industrial and populated areas have the highest dissolved-solids concentration (130-450 parts per million), hardness of water (80–300 ppm), synthetic detergents (0.2–1.0 ppm), turbidity (30–50 Jackson candle units), and coliform bacteria (exceeding 50,000 most probable number). Streams that receive drainage from farmlands also tend to have relatively high turbidity (10–20 Jcu) and coliform bacteria (10,000–50,000 mpn) concentrations.

Average dissolved solids in the State's streams normally range from 20 to 450 ppm; hardness of water, from 5 to about 300 ppm; iron, 0.0 to about 5.0 ppm; turbidity, 5 to 50 Jcu; and coliform bacteria, from less than 10,000 to more than 100,000 mpn. Synthetic detergents range from 0.0 to 1.0 ppm. Estimated sediment yield varies from 10 to 500 tons per square mile according to the stream location.

Stream temperatures generally follow the seasonal variation of air temperature but also are closely related to drainage area, stream width, relative shade from solar radiation, and amount of ground-water inflow.

The effects of tidal invasion of saline water on the water quality of an estuary are related to the distance from the ocean, fresh-water inflow, range and stage of tide, and climatological conditions. Examples of such effects are given for two location in the Delaware estuary.

INTRODUCTION

In 1962 the U.S. Geological Survey and the State of New Jersey entered into a cooperative long-range program to appraise the water quality of streams in the State. Participants in this cooperative effort are the New Jersey State Department of Health, Division of Environmental Health; the State Department of Conservation and Economic Development, Division of Water Policy and Supply and Division of Fish and Game; the State Department of Agriculture, Soil Conservation Committee; and the U.S. Geological Survey, Water Resources Division.

The initial effort in this cooperative program was a reconnaissance of present knowledge of the stream systems of New Jersey in relation to problems of water quality, as a basis for more specific investigations. The study includes the appraising of basic data collected by State and other groups, collecting additional facts as necessary to gain a broad perspective, designing sample-collection programs and specific problem-oriented project studies, and determining with wide flexibility what further work should be done.

This paper discusses the results of the statewide reconnaissance made during 1962 and 1963 and evaluates data collected by the State Department of Health and others since 1950. The report gives brief discussions of the relations between water quality and several environmental factors—streamflow, geologic terrane, precipitation, cultural environment, and tidal invasion of salt water. The variations, both with area and with time, of several water-quality parameters—dissolved solids, hardness, dissolved oxygen, water temperature, suspended sediment, beta activity, iron, synthetic detergents, turbidity, and coliform bacteria—are described. Although emphasis has been placed on the chemical character of the nontidal parts of New Jersey's streams, brief discussions of tidal effects and of the physical and bacterial characteristics of streams have also been included.

PREVIOUS AND CONCURRENT INVESTIGATIONS

The importance of water-quality studies of streams in New Jersey was recognized early in the State's history. Chemical analyses of water samples from the larger rivers were included in the first annual report of the State geologist (Cook, 1868), and many of the later annual reports also contained analyses of river water. In the State geologist's 12-volume "final" report, Vermeule (1894) included several chemical analyses of river water to give "a general idea of the chemical composition of the various waters of the State in their natural condition."

In 1923 the North Jersey District Water Supply Commission began periodic collection and analysis of water samples at several gaging stations in northern New Jersey. The State Department of Conservation and Economic Development in 1927 assumed the responsibility for collecting and analyzing samples at these stations and increased the number of sampling locations to cover the entire State. Since 1930 the State Department of Health has been responsible for the entire sampling program and, except for the period 1942–58, has operated an extensive basic water-quality-data program. Generally, records collected by the North Jersey District Water Supply Commission and the State agencies are unpublished but are available from the State Division of Water Policy and Supply (1923–32) and the State Division of Environmental Health (1930–42, 1958–65).

Presently (1965), more than 150 water-quality stations are operated by the State Department of Health (pl. 1). Samples normally are collected quarterly to represent seasonal variations in quality. Most sampling sites are at or near gaging stations. Analytical determinations include the following: color, odor, turbidity, dissolved solids, residue after ignition, ammonia nitrogen, organic nitrogen, nitrites, nitrates, chlorides, alkalinity, hardness, iron, pH, dissolved oxygen, biochemical-oxygen demand, and coliform bacteria.

Prior to the present study, few investigations of the quality of streams in New Jersey were made by the U.S. Geological Survey.

During the period 1923–26, water samples from major streams in the State were collected and analyzed by the Geological Survey in cooperation with the State Department of Conservation and Economic Development. Most samples were collected at gaging stations to relate chemical composition to streamflow. Chemical analyses of these streams and a brief discussion of their suitability for different types of industrial use were reported by Collins and Howard (1927). These data were used more recently in an article discussing the water quality of streams in New Jersey, Delaware, Maryland, and Virginia (Love, 1950).

A brief study of the chemical character of water in the Delaware and Raritan Canal, using a continuous-recording specific conductance instrument and intermittent sampling for chemical analysis, was conducted during 1955–57 in cooperation with the State Division of Water Policy and Supply. Results of this study are published in the Geological Survey's annual Water-Supply Paper series on the "Quality of Surface Waters of the United States."

Sediment-discharge data are being collected from Stony Brook, a major tributary of the Millstone River, and in the South Branch Raritan River basin. The sediment-discharge data from the Stony Brook basin are being used to determine the effects of major land-use changes on sediment yield from the basin. The study is being carried out in cooperation with the State Soil Conservation Committee; a progress report was released recently (George, 1963).

Another study in the Stony Brook basin was started in 1961, also in cooperation with the State Soil Conservation Committee, to measure the trap efficiency of Baldwin Lake, a small reservoir in the basin. Periodically, a comparison is made of the quantity of sediment retained by the reservoir with that discharged.

A study in the South Branch Raritan River basin is being made to anticipate the chemical and physical quality of water to be stored in the newly constructed Spruce Run and Round Valley Reservoirs. This study is being made cooperatively with the State Division of Water Policy and Supply.

Additional studies have been reported on by the Geological Survey in its cooperative investigations of water quality in the Delaware River basin. In a report on the quality of streams in Pennsylvania, Durfor and Anderson (1963) devoted several pages to the Delaware River, which forms New Jersey's western boundary and whose tributaries drain about one-third of the State. In addition, Anderson and McCarthy (1963) mapped the prevalent chemical characteristics of streams in the entire basin, and McCarthy and Keighton (1964) reported on the quality of the Delaware River at Trenton, N. J., as affected by drought, flood, reservoir operation, streamflow regulation, geologic environment, and increased population. Several reports (Durfor and Keighton, 1954; McCartney and Beamer, 1962; Cohen and McCarthy, 1962; Miller, 1962; Keighton, 1965) also have been published on water-quality investigations in the Delaware estuary.

Extensive use was made in the preparation of this report of the basic hydrologic data collected in the Geological Survey's surface-water and ground-water programs, which are conducted mainly in cooperation with the State Division of Water Policy and Supply.

Systematic records of streamflow have been collected and appraised at about 100 gaging stations throughout the principal river basins in the State. Records have been collected at many of these stations continuously since the early 1920's and at two prior to 1898. The records are published in several State reports and, since 1961, in an annual basic-data release by the Geological Survey entitled "Surface Water Records of New Jersey."

Studies of the ground-water resources in the State have been reported in publications of the State Department of Conservation and

Economic Development since the mid-19th Century. More recently, the availability, distribution, and chemical quality of the State's ground-water resources have been and are being appraised—in anticipation of greater future water needs—by the U.S. Geological Survey in cooperation with the State Division of Water Policy and Supply. Detailed ground-water studies have been completed and reported in State publications (as of 1965) on four counties, Middlesex, Cape May, Morris, and Mercer, and for seven critical areas in the State.

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The authors wish to acknowledge the assistance received from their coworkers—especially John E. McCall, district engineer, and Allen Sinnott, district geologist, for providing hydrologic data. The report was prepared under the general supervision of Norman H. Beamer, district chemist.

WATER QUALITY AND ENVIRONMENT

The quality of water in a stream is essentially the sum of the quality of the several components that make up the streamflow. For example, during a flood discharge the chemical quality of a stream approximates that of the principal streamflow component, direct overland runoff. Conversely, the quality of a stream during extremely low flow conditions—when the stream is maintained by ground-water effluents—approximates or is similar to that of these effluents. Other factors that influence streamflow—such as forest cover, land cultivation, geologic terrane, degree and type of urbanization, and industrial-waste disposal—have their influence on the quality of a stream. The remainder of this section outlines in general terms the individual effects of the major streamflow components on the quality of the State's streams.

Because of its unique ability to dissolve more substances than any other liquid can dissolve, water is unable to remain entirely pure in the hydrologic cycle. As precipitation falls through the atmosphere, it absorbs gases such as carbon dioxide and oxygen and picks up dust particles, bacteria, and spores. If the air is contaminated with industrial and automotive fumes, other gases such as sulfur dioxide, ammonia, and carbon monoxide also are absorbed. Thus, when precipitation reaches the earth, it usually is carrying small amounts of dissolved and suspended matter.

The dissolved-solids concentration of precipitation can be quite variable. Analyses of 50 samples of rain and snow collected in the Coastal Plain part of the State (fig. 5) showed that dissolved solids ranged from about 10 to 500 ppm (parts per million). Half of these samples, however, were collected during tropical storms and thus are not representative of normal rainfall conditions. E. C. Rhodehamel and H. E. Gill (U.S. Geol. Survey, written commun.) in a study of two tropical storms, Helene (Sept. 28, 1958) and Donna (Sept. 12, 1960), observed chloride concentrations as high as 200 ppm in rainfall near New Jersey's beaches. They reported that the concentrations dropped rapidly to about 5 ppm at stations 15 miles inland. The concentration of dissolved solids in precipitation on New Jersey probably does not exceed 30 ppm except during extreme climatological conditions, such as these storms.

During and for several days after moderate-to-heavy precipitation, the major part of water flowing in a stream is the result of direct overland runoff. This stream water has had little contact time with soluble materials, and its dissolved-solids concentration generally approaches that of precipitation. The concentration of dissolved solids in a stream during high-flow conditions, therefore, usually is at a minimum (fig. 1).

During sustained periods of fair weather, the flow in a stream is maintained largely by ground-water inflow. Consequently, the dissolved-solids concentration during low-flow conditions reflects that of the ground-water inflow. Because this ground water usually contains more dissolved solids than the surface runoff, owing to the longer duration of its contact with soluble materials, the dissolved-solids concentration in most streams is at a maximum during periods of low flow (fig. 1). Furthermore, during such periods, minor increases in discharge generally have a greater effect upon the dissolved-solids concentration than similar increases during periods of median or higher streamflow.

Under natural conditions the dissolved solids in a stream during intermediate-flow conditions are a composite of the quality of both the ground-water inflow and the direct runoff and are regulated by the amount of streamflow contributed by each source.

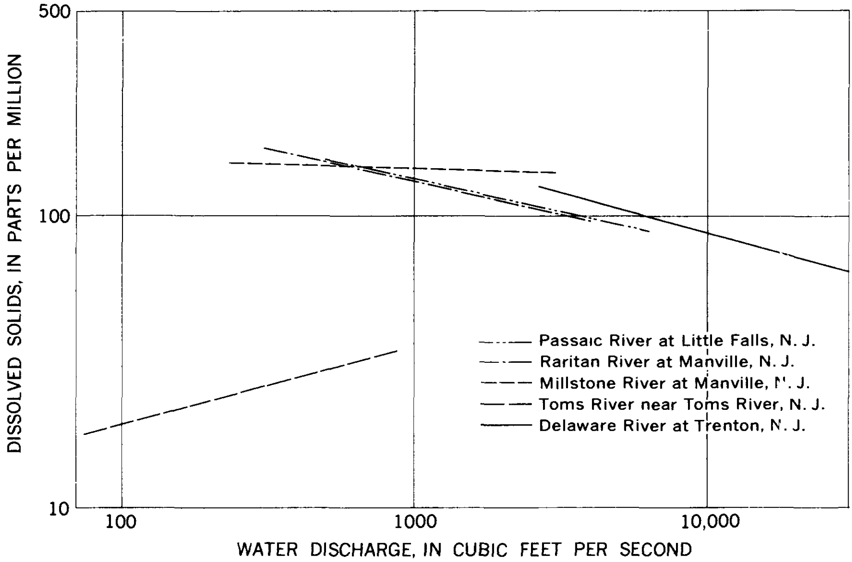

FIGURE 1.—Relation of dissolved solids to streamflow at five stream locat'ons in New Jersey, 1956–62.

Many streams in New Jersey show an inverse relation between dissolved-solids concentration and streamflow (fig. 1), that is, with an increase in streamflow there is a corresponding decrease in dissolved solids. However, most streams in the Coastal Plain, that drain into the Atlantic Ocean and Delaware Bay show a direct relation. The data illustrated for Toms River (fig. 1) are used as an example of this phenomenon. Note that as streamflow increases, the dissolved-solids concentration also increases. Preliminary data indicate that the increase in dissolved solids in these streams is due to an increase in the concentrations of sulfate and bicarbonate ions.

The unusual relation of dissolved solids to water discharge in streams in the Coastal Plain possibly can be explained by the character of the soils in this area. These soils have exceptionally high infiltration rates, and thus there is little direct overland runoff to the stream channels. Consequently, most of the water in these streams can be attributed to ground-water inflow. During low-flow conditions, as mentioned earlier, the chemical quality of water in a stream approximates that of ground-water inflow. This condition appears to be true for the streams under discussion (table 6). However, this statement does not explain the increase in dissolved solids with increasing streamflow that occurs even during prolonged periods of high flow. One possible explanation is the dissolution, during these high-flow periods, of soluble salts left by the previous evaporation of swamp and marsh waters during dry conditions and by the decay of vegetation; the subsequent flushing of these more concentrated waters from the land surface by precipitation thus would increase the dissolved-solids concentration of the streams.

The relation between streamflow and dissolved-solids concentration differs from stream to stream (fig. 1) and may also change along the reach of a stream, as shown on figure 2. Near Barryville, N.Y., the most upstream Delaware River station plotted, the slope of the water-discharge versus dissolved-solids line is slight, an indication that the dissolved-solids concentration is little influenced by streamflow. Tributaries draining into the Delaware River below Barryville contain higher concentrations of dissolved solids through all ranges of streamflow than do streams draining above Barryville. The cumulative effect of these inflowing streams produces the shift in the relation between dissolved solids and streamflow. At Port Jervis, N.Y., Easton, Pa., and Trenton, N.J., the slope of the line is increasingly greater; thus, changes in concentration of dissolved solids with streamflow are greater. Figure 2 also shows that the dissolved-solids concentration increases in a downstream direction, a common phenomenon for most streams in the State.

In a paper recently presented before the New Jersey Section of the

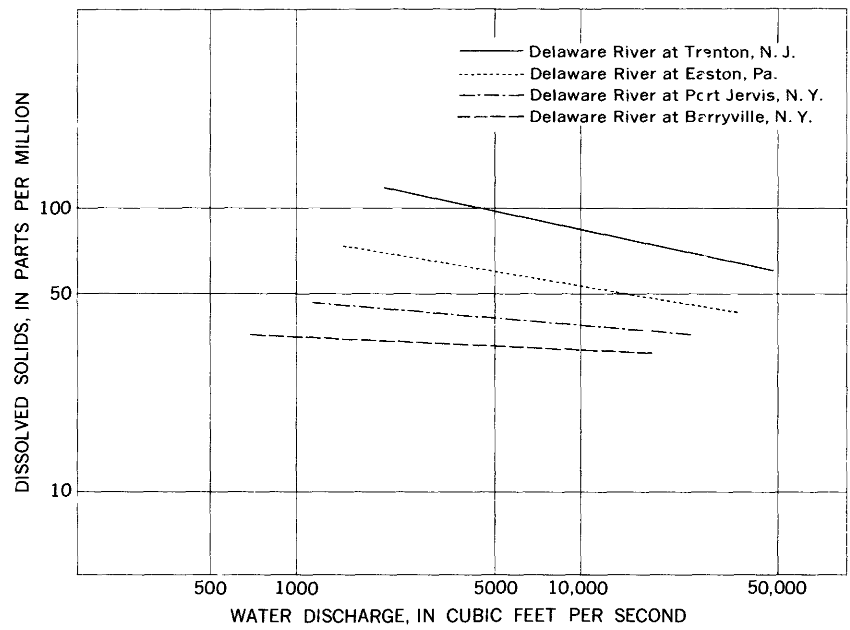

Figure 2.—Relation of dissolved solids to streamflow at four locations on the Delaware River, 1957–58.

American Water Works Association, George and Anderson (1963) pointed out that the concentrations of many of the individual constituents dissolved and suspended in the water, as well as the total dissolved solids, are related to streamflow. The concentration of calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, dissolved oxygen, and suspended sediment and the hardness of water often can be related significantly to streamflow in New Jersey.

The natural quality of many streams in New Jersey has been changed by manmade variations in the natural regimen of the drainage basin. For example, the discharge of chemical wastes, treated or untreated, by industrial or agricultural users of water can increase the dissolved-solids content of the receiving streams. Each year, detergents, insecticides, and similar synthetic products find their way into streams from sewers, septic tanks, or land runoff. Even local control of streamflow by impoundment has both beneficial and detrimental effects on water quality (Love, 1961).

Land use also has a major influence on water quality. During most of the year, streams draining forested areas tend to be low in dissolved solids. However, as the vegetative litter of forests, swamps, and wetlands decomposes, the dark-colored nitrogeneous products of this decomposition are carried by direct runoff into the nearby receiving streams. Consequently, when these conditions prevail, the color, nitrate, and iron content of the receiving streams are increased. Streams draining cultivated lands also are influenced. Fertilizers applied to farmlands are dissolved by precipitation or by irrigation water which, in turn, infiltrates to the ground water or runs off to nearby streams and contributes significantly to their potassium, nitrate, and phosphate content. Runoff from farmlands often carries soil bacteria with it.

The quantity of suspended, as well as dissolved, material delivered to streams by direct runoff is closely related to the amount of protective cover; the cover tends to inhibit erosion and transport of these materials. George (1963) reported a 25-percent increase in sediment yield in the Stony Brook basin during the last half of the period 1956–59. He concluded that land stripped for urban expansion and reservoir construction in the basin was creating a temporarily high suspended-sediment yield.

Thus, changes in land use often produce changes in the water quality of receiving streams. Although most land-use changes are intended to benefit mankind, available supplies of natural water often suffer a resultant deterioration in quality unless the changes are controlled by efficient water management.

This report is basically on the nontidal reaches of the State's streams. It, however, would be incomplete without a brief discussion concerning tidal effects, as practically all major streams in New Jersey are affected by tides in their lower reaches. Much of the area adjacent to the Atlantic Ocean and to the Delaware, Newark, and Raritan Bays also contains extensive tidal marshes, meadows, and wetlands. The effects of the tides often extend far inland. For instance, the head of tidewater on the Passaic River is about 14 miles above its mouth on Newark Bay; on the Raritan River, about 12 miles above its mouth on Raritan Bay; and on the Delaware River, about 80 miles above Delaware Bay, or 130 miles from the Atlantic Ocean.

Salty or brackish water from the ocean and bays is carried upstream in the estuaries by each flood tide and downstream by each ebb tide. The extent of such tidal invasion into the estuaries is evidenced by the concentration of dissolved solids and by the proportions of the various mineral constituents. For example, sea water contains three times as much magnesium as calcium, whereas fresh water normally contains twice as much calcium as magnesium. Furthermore, ocean water contains about 35,000 ppm of dissolved solids, of which about 19,000 ppm are chloride ions.

The extent of tidal invasion of salt water in an estuary is dependent on a number of factors, some of which are fresh-water inflow, quantity of salt water moving upstream from the ocean, range and stage of tide, and climatological conditions. In late summer and early fall, fresh-water flow is usually at a minimum, and the mean sea level, which partly controls the movement of salt water into the estuary, is at a maximum. These conditions are favorable for the movement of salty water upstream. In late October or early November, fresh-water flow generally increases, sea level decreases concurrently, and the salt water recedes downstream.

The effects of tide on dissolved solids in an estuary are illustrated on figure 3, two locations in the Delaware estuary being used as examples. In the lower reaches of an estuary the maximum and minimum concentrations of dissolved solids occur after the maximum and minimum tidal stages—at about the time of slack water (lower curve on fig. 3). In the upper reaches of an estuary—for example, at Philadelphia (upper curve, fig. 3)—where salt water has not come upstream, the salinity of the river water is little affected by the tides.

Several reports on the Geological Survey's studies on water-quality characteristics of the Delaware estuary (Durfor and Keighton, 1954; McCartney and Beamer, 1962; Cohen and McCarthy, 1962, Keighton, 1965) have been published recently.

In summary, the water quality of New Jersey's streams is influenced by the quality of the individual components of streamflow (that is,

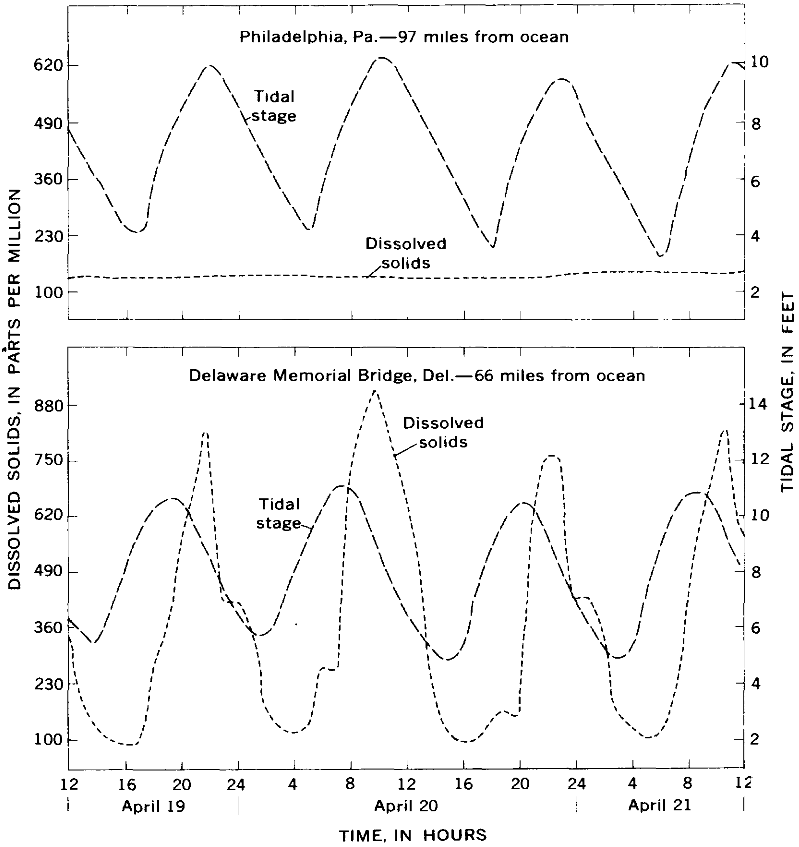

Figure 3.—Variation of dissolved solids with tidal stage at two locations in the Delaware estuary, April 19–21, 1963.

precipitation, direct overland runoff, and ground-water inflow to the stream); by the cultural environment; and in some cases by tidal invasion of salt water. The quality of any stream can usually be attributed to a combination of two or more of these causative factors.

WATER-QUALITY VARIATIONS

In its endless hydrologic cycle, water carries many types of dissolved and suspended materials. Studies of the concentration, composition and movement of these materials can generally be arranged in three categories of water quality: chemical, physical, and bacterial. Normally, studies of chemical quality provide information on the dissolved constituents in the water; physical quality, the suspended materials and physical properties; and bacterial quality, the amount and type of bacteria commonly found in the stream.

Because of the interrelation between many water-quality parameters, it is often difficult to understand one without a knowledge of the others. Thus, water-quality studies frequently are concerned with more than a single category of quality. For example, a stream-pollution study would include parts of each category: chemical, physical, and bacterial. Tests would include measurements of the density of particular bacteria groups, of water temperature, of turbidity, of alkalinity, of chloride content, and of many other factors of chemical and physical quality, depending upon the source of pollution.

In appraising the development of a water source, or the expanded use of a partly developed source, a water user often finds that an adequate knowledge of water quality is just as important as information on quantity and distribution. Although today almost any water can be treated by specific processes to produce a water of desired quality, economics determines the extent to which such treatment is practicable. Thus, the chemical, physical, and bacterial properties ultimately may determine the suitability of a stream for a particular use.

CHEMICAL QUALITY

Excessive concentrations of various chemical constituents make a particular water unusable for certain purposes. Consider, for instance, a potential potable-water supply. The New Jersey Department of Health (1962) requires that:

> Drinking water shall not contain impurities in concentrations which may be hazardous to the health of the consumer. It should not be excessively corrosive to the water supply system. Substances used in its treatment shall not remain in the water in concentrations greater than required by good practice. Substances which may have a deleterious physiological effect, or for which physiological effects are not known, shall not be introduced into the system in a manner which would permit them to reach the consumer.

The allowed maximum and the recommended maximum concentrations of specific chemical substances in New Jersey's potable water-supply systems are listed below:

Constituent	*Maximum (parts per million)*
Arsenic	0.05
Barium	1.00
Cadmium	.01
Chromium (hexavalent)	.05
Cyanide	.20
Fluoride	1.50
Lead	.05
Selenium	.01
Silver	.05

Constituent	*Recommended maximum (parts per million)*
Alkyl benzene sulfonate	0.05
Chlorides	250.0
Copper	1.0
Iron	.3
Manganese	.05
Nitrates	20.0
Phenolic compounds	.001
Sulfate	250.0
Total dissolved solids	500.0
Total hardness	170.0
Zinc	5.0

The presence of chemical substances in excess of the maximum concentrations listed "shall constitute grounds for rejection of the supply." The presence in excess of recommended maximum concentrations listed "may constitute grounds for the rejection of the supply if, in the opinion of the Department, such substances, either singly or in combination, are present in such concentrations as would render the water unduly corrosive, unpalatable, hazardous to the consumers, or aesthetically objectionable."

Tolerances for chemicals in water for industrial uses differ widely. For instance, cooling water may be of poor quality, provided it meets the necessary temperature requirements, but boiler-feed water under high pressure must be of extremely good quality. Most industrial processes require water containing no more than 500 ppm of dissolved solids; only a few processes can permit 1,000 ppm or more.

The chemical quality of water is an important consideration in agriculture. A plant cannot draw as much water from a concentrated-soil solution as it can from a dilute one. Under most conditions, 700 ppm or less of dissolved solids is satisfactory for irrigation water. Minimum concentrations of certain chemicals are essential for plant growth, but excess concentrations of these same chemicals can be toxic. Consider boron, an essential element in the nutrition of plants, yet concentrations in excess of 0.5 ppm are toxic to many crops.

Quality requirements to support aquatic life are often stringent; dissolved-oxygen content, temperature, and pH are among the important parameters.

For those interested in water-quality criteria, additional information is available in publications of the U.S. Public Health Service, the California Water Pollution Control Board, and the Ohio River Valley Water Sanitation Commission.

REGIONAL VARIATIONS

Data collected at more than 100 locations (pl. 1) by the State Department of Health are used to describe the regional variations in water quality presented in the following sections. Other sources of data used in the areal descriptions are acknowledged in the text.

DISSOLVED SOLIDS

The chemical character, as well as the dissolved-solids concentrations, of streams throughout the State, above the influence of tides, is mapped areally on figure 4. These areal groupings of streams are based on the predominant chemical constituents and thus indicates the types of water that prevail in various geographic areas. A few streams in each region may not fall within these general limitations. A comparison of these regions of isochemical quality and the physi-

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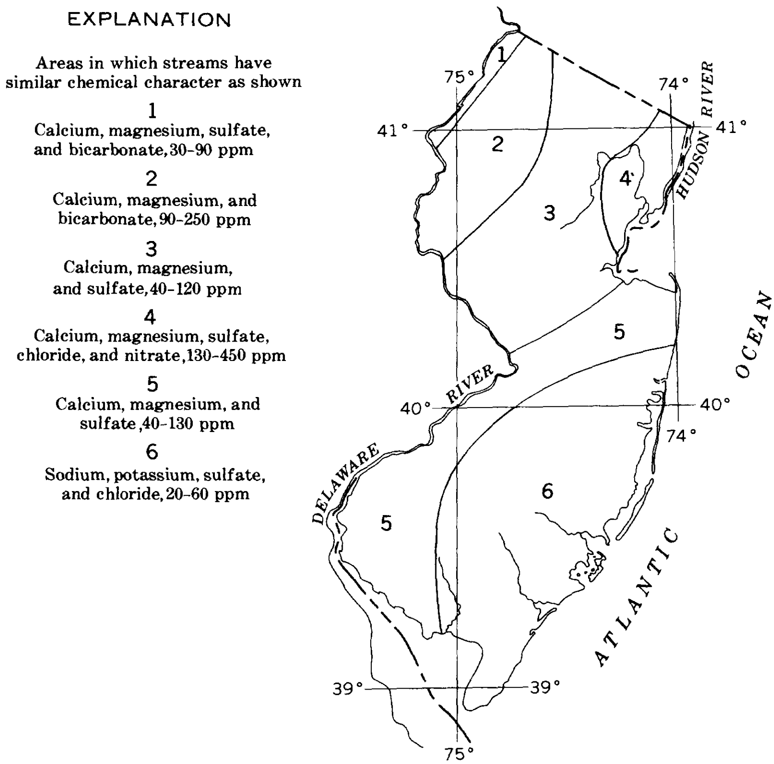

Figure 4.—Prevalent chemical character and dissolved-solids concentrations of streams of New Jersey.

ographic divisions (fig. 5) of the State indicates a definite relation between the two.

Streams in region 1 (fig. 4), notably Flat Brook and its tributaries, drain rough mountainous, heavily wooded lands of the glaciated Valley and Ridge province. The region is underlain by shale, sandstone, and conglomerate beds of Devonian and Silurian age. Intense Pleistocene glaciation has left extensive glacial-drift deposits. The virtual lack of solutes in these drift deposits and the high runoff rates have a dominant influence on the chemical quality of streams in this region.

Dissolved-solids concentrations in region 1 normally range from 30 to 90 ppm. The predominant ions are calcium, magnesium, sulfate, and bicarbonate. Near the mouth of Flat Brook the amount of bicarbonate ions exceeds that of sulfate ions, but in the headwaters the amount of sulfate ions exceeds that of bicarbonate. Representative chemical analyses of streams in this region are presented in table 1.

Streams in region 2 (fig. 4), notably Paulins Kill, Pequest River, and Musconetcong River in the Delaware River basin and the Wallkill

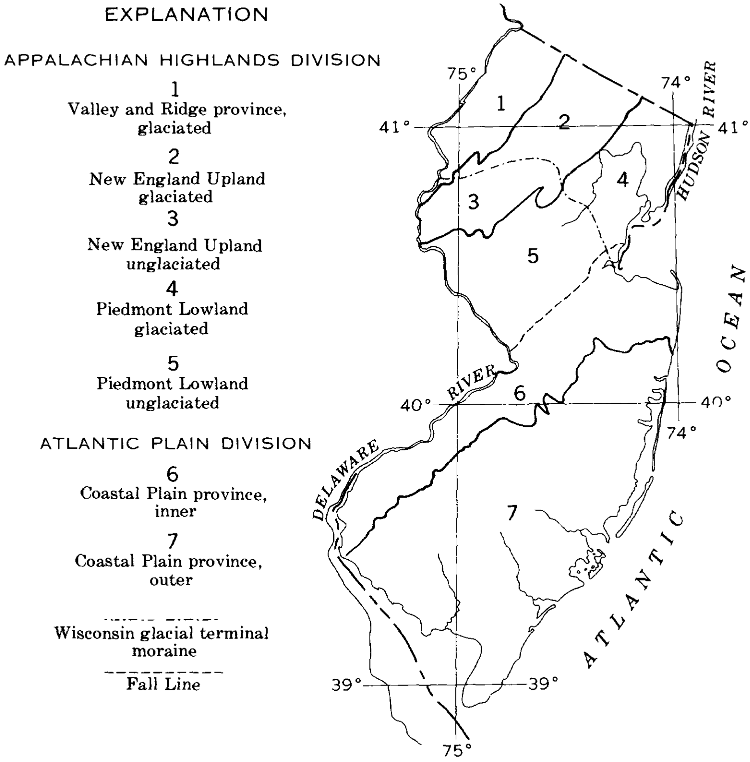

FIGURE 5.—Physiographic divisions of New Jersey, based on a map by Rogers (1955).

River in the Hudson River basin, drain the Valley and Ridge province and the New England Upland section. The topography ranges from low well-rounded hills and valleys in the south to the ridge of Kittatinny Mountains along the northern boundary. Except for small forested areas, the region is mostly farmland.

The geologic terrane of region 2 is complex. Extensive beds of Cambrian and Ordovician limestone and dolomite throughout the region greatly influence the chemical quality of streams. Water issuing from them contains high concentrations of calcium, magnesium, and bicarbonate, and consequently, these ions predominate in the streams traversing the limestone and dolomite deposits. Dissolved solids in the streams range from 90 to 250 ppm, the high concentrations occurring in streams that receive relatively large inflow from limestone and dolomite deposits. Representative chemical analyses of streams and shallow wells (less than 75 feet in depth) in this region are presented in table 2.

TABLE 1.—*Representative chemical analyses, in parts per million, of selected streams in region 1 (fig. 4)*

[Analyses by U.S. Geol. Survey]

Location	Date of collection	Mean discharge (cfs)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C.)	pH
									Calcium, magnesium	Noncarbonate		
Delaware River basin:												
Shimers Brook near Montague	9-28-60	12.5	----------	----------	100	----------	----------	----------	----------	----------	177	8.0
	9-26-61	2.02	4.4	----------	145	18	4.0	0.9	142	15	263	8.4
Flat Brook near Flatbrookville	8-10-62	27	2.5	0.6	91	22	3.0	.8	95	20	196	7.1
	9-6-62	22	2.1	1.0	38	20	3.8	.2	52	21	121	7.3
Vancampens Brook near Millbrook	9-26-61	3.84	3.7	----------	34	11	3.0	.4	36	8	80	7.5
	4-12-62	27.0	1.6	----------	12	12	2.0	.2	22	12	55	6.8
Stony Brook near Columbia	9-26-61	.55	9.2	----------	38	12	3.0	.4	38	0	98	8.9
	4-12-62	9.16	.5	----------	11	14	1.0	.0	24	15	62	7.1

TABLE 2.—*Representative chemical analyses, in parts per million, of selected streams and wells in region 2 (fig. 4)*

[Analyses by U.S. Geol. Survey]

Location	Date of collection	Mean discharge (cfs)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25° C.)	pH
									Calcium, magnesium	Noncarbonate		
Hudson River basin:												
Wallkill River at Franklin	9-6-61	8.31	------	------	156	18	13	------	148	20	303	7.6
	4-5-62	74.3	5.0	0.8	66	17	9.8	0.8	71	17	167	7.2
Papakating Creek at Pellettown	9-5-61	1.82	------	------	103	28	9.0	------	120	32	258	8.4
	4-5-62	25.3	5.3	------	42	26	6.0	4.4	62	28	154	8.0
Clove Brook at Sussex	9-6-61	3.58	------	------	74	23	8.0	------	86	26	196	7.1
	4-5-62	39.9	7.4	------	[1] 34	20	8.5	4.3	50	21	134	8.6
Raritan River basin:												
South Branch Raritan River near High Bridge	2-26-61	910	2.2	1.5	16	15	3.0	4.0	70	15	78	6.5
	8-3-62	27	5.0	1.0	107	9.9	3.5	3.4	93	5	199	7.3
Spruce Run at Clinton	2-25-61	450	2.2	2.0	20	22	3.0	4.4	40	24	103	6.8
	8-3-62	6.6	6.2	1.5	75	21	6.1	.5	75	14	181	6.8
South Branch Raritan River at Stanton	8-1-61	414	4.1	1.8	50	16	4.5	3.6	56	15	130	6.9
	7-18-62	40	5.6	1.5	104	14	5.4	2.3	97	12	206	7.9
Delaware River basin:												
Paulins Kill at Blairstown	8-25-60	351	4.8	2.2	128	28	6.4	3.5	136	31	276	7.7
	8-10-62	39	6.6	1.2	165	27	9.8	1.3	173	38	334	7.0
Pequest River at Huntsville	8-17-62	4.5	4.3	1.3	218	27	8.5	1.4	210	31	411	7.7
Lopatcong Creek at Phillipsburg	9-6-61	11.4	------	------	168	31	9.0	------	180	43	357	7.5
	4-5-62	18.4	------	------	120	------	------	------	139	41	295	7.9
Pohatcong Creek at New Village	8-9-62	15	12	6.4	68	32	12	3.8	76	20	238	6.7
Pohatcong Creek at Carpentersville	9-6-61	26.4	------	------	144	29	6.0	------	148	30	298	7.4
	4-5-62	65.2	5.3	2.2	76	33	6.8	6.0	97	35	220	7.3
Musconetcong River at Outlet of Lake Hopatcong	8-14-62	11	5.2	1.0	23	16	8.0	1.0	37	18	170	6.5
Musconetcong River near Hackettstown	8-17-62	18	5.8	.3	86	21	7.8	.0	91	21	213	6.5
Wells:												
Andover	5-11-59	------	6.0	1.5	216	25	16	8.4	208	31	423	7.7
Califon	7-29-59	------	7.6	.8	45	14	6.0	12	54	17	148	6.4
Hamburg	4-30-59	------	7.0	2.0	282	36	10	6.6	259	28	505	7.3
Hughesville	7-27-59	------	6.7	1.7	126	22	5.2	4.8	119	15	263	7.4
Milford	7-27-59	------	15	1.4	149	66	7.2	6.5	168	46	392	7.6
Netcong	7-29-59	------	5.0	.3	111	16	2.1	3.3	101	10	210	7.9
Sparta	2-28-57	------	4.2	2.1	200	9.6	5.9	6.5	175	3	357	8.4
Warren Glen	7-27-59	------	6.2	1.3	124	19	4.3	2.1	117	16	245	7.6

[1] Includes equivalent of 2 ppm of carbonate (CO_3).

Region 3 (fig. 4) lies mostly within the Piedmont Lowland section, which is characterized by low well-rounded hills and shallow valleys. Streams in this region include Harihokake, Lockatong, Wickecheoke, and Jacobs Creeks, which drain into the Delaware River basin; most streams in the Raritan River basin; and the headwaters of the Passaic, Whippany, and Rockaway Rivers, and the entire Pequannock, Wanaque, Ramapo, and Pompton River systems in the Passaic River basin. Precambrian crystalline rocks predominate in the northern part of region 3, whereas the southern part is underlain by Mesozoic sandstone, shale, conglomerate, and diabase. Quaternary deposits of thin unconsolidated sand and gravel are present in the flat Coastal Plain along the extreme southern boundary of the region.

The diverse geologic terrane causes considerable variation in the chemical character of streams in region 3. Calcium and magnesium are the predominant cations in most of the streams. The predominant anion in the water is sulfate, especially in those streams draining the Triassic sediments, although 30 to 50 percent of the anions is bicarbonate. Therefore, region 3 is differentiated from region 5, which has 0 to 20 percent bicarbonate. The dissolved-solids concentrations of most streams range from 40 to 120 ppm. However, streams draining the Precambrian rocks and glacial-drift deposits, notably the Pequannock, Wanaque, and Rockaway Rivers, usually have lower concentrations of dissolved solids, ranging from 40 to 100 ppm, than streams in the southern part of the region. Representative chemical analyses of streams and shallow wells in this region are presented in table 3.

The topographic and geologic environments in region 4 (fig. 4) are similar to those in the southern part of region 3, and the original chemical character of streams in this region was similar to that in region 3. However, many streams in the Hackensack, Elizabeth, Rahway, and lower Passaic River basins receive industrial and domestic wastes from the highly populated and industrial metropolitan area in the northeastern part of the State. These wastes adversely affect the chemical character of streams in region 4, as indicated by their much higher concentrations of chloride, nitrate, and dissolved solids. In fact, the highest dissolved-solids concentrations in the State's streams, above the influence of tides, are found in this region, where they range from 130 to 450 ppm. Representative chemical analyses of streams and shallow wells in region 4 are presented in table 4.

Streams in region 5 (fig. 4) drain small areas, and runoff is normally low. The land is fertile and highly cultivated. The chemical character of streams in this region is similar to that in region 3, predominant ions in both regions being calcium, magnesium, and sulfate.

TABLE 3.—*Representative chemical analyses, in parts per million, of selected streams and wells in region 3 (fig. 4)*

[Analyses by U.S. Geol. Survey]

Location	Date of collection	Mean discharge (cfs)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C.)	pH
									Calcium, magnesium	Noncarbonate		
Passaic River basin:												
Passaic River near Millington	8-22-62	13	9.0	1.6	52	31	8.2	0.2	66	24	185	6.7
	11- 8-62	56	7.9	2.8	28	27	11	1.0	52	29	151	6.5
Passaic River near Chatham	8-22-62	24	60	4.0	74	34	79	5.7	87	27	475	6.8
Rockaway River at Berkshire Valley	4- 5-62	93.7	2.0	.5	16	14	3.6	.9	30	17	74	5.9
Rockaway River above Reservoir at Boonton	8-28-62	119	5.8	1.5	58	18	7.5	2.2	64	17	183	7.5
	11- 8-62	118	4.5	.9	38	22	6.1	.7	55	24	145	6.5
Whippany River at Morristown	8-23-62	15	14	2.8	48	33	16	13	76	36	237	6.7
	11- 8-62	19	9.0	2.0	46	28	11	9.3	71	34	206	6.6
Pequannock River at Macopin Intake Dam	11-28-62	5.0	3.8	.2	18	18	6.4	.2	32	17	95	6.7
Wanaque River at Wanaque	7-31-62	17	3.6	.8	23	17	5.6	.6	36	17	96	6.5
	11-30-62	16	4.2	.5	30	19	7.0	2.8	46	22	123	6.6
Ramapo River at Pompton Lakes	8-10-62	69	13	1.2	83	23	16	2.8	92	24	234	8.1
	11-28-62	336	5.2	.5	36	22	8.4	1.2	54	25	141	6.9
Raritan River basin:												
North Branch Raritan River near Far Hills	8-14-62	8.3	5.2	1.5	48	15	4.8	3.2	52	13	131	6.8
	11- 7-62	19	5.0	1.8	44	17	6.2	.9	50	14	131	7.0
North Branch Raritan River near Raritan	8-24-62	55	12	1.2	79	22	7.0	1.8	71	7	202	7.8
	11-14-62	236	7.4	1.8	44	29	6.9	3.8	65	29	169	7.0
Raritan River at Manville	8-24-62	115	24	1.9	85	143	13	.6	188	119	466	7.2
	11-13-62	716	8.2	2.3	40	49	8.2	6.6	86	53	220	6.9
Stony Brook at Princeton	7- 6-60	2.2	11	2.5	68	28	10	.9	69	14	186	7.7
	3-23-61	1,140	4.0	2.0	6	20	4.0	5.8	27	22	92	6.4
	7-18-62	3.2	15	2.8	72	34	16	.7	85	26	239	7.5
Millstone River at Blackwells Mills	8-24-62	65	13	3.3	37	39	16	4.1	66	35	211	6.6
	11-13-62	428	8.4	4.1	22	38	13	6.9	64	46	184	6.3
Wells:												
Boonton	3- 4-59		4.5	1.3	76	26	5.8	11	92	29	216	6.8
Canoe Brook	2-24-59		19	.8	124	77	7.7	1.2	154	52	375	7.9
Clarksville	4-15-58		16	2.7	12	48	26	68	112	102	342	5.9
Dover	7-30-59		8.4	1.7	151	26	8.6	3.9	149	25	322	6.9
Essex Fells	2-25-59		7.6	.4	126	46	11	8.8	162	58	345	7.4
Manville	3- 3-59		7.0	1.0	58	35	7.8	6.1	83	35	206	7.5
Milburn Township	2-24-59		14	.5	154	73	7.5	6.4	192	66	415	7.9
Oakland	4-29-59		6.0	.5	106	20	7.4	10	110	[illegible]	245	7.8

TABLE 4.—*Representative chemical analyses, in parts per million, of selected streams and wells in region 4 (fig. 4)*

[Analyses by U.S. Geol. Survey]

Location	Date of collection	Mean discharge (cfs)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH
Hackensack River basin:												
Hackensack River at Rivervale	8-14-62	33	14	2.5	89	28	22	4.7	108	35	283	7.2
Pascack Brook at Westwood	8-14-62	17	15	1.7	118	29	20	1.0	134	37	335	6.9
Hackensack River at New Milford	8-14-62	.1	11	1.7	76	28	15	1.1	94	32	244	6.4
	12- 6-62	300	9.6	2.2	69	32	13	1.7	92	35	251	6.6
Passaic River basin:												
Passaic River at Little Falls	7-30-62	68	30	3.0	70	44	30	5.1	89	32	323	6.8
	11-27-62	840	9.0	1.5	32	37	12	4.8	66	40	196	6.5
Saddle River at Ridgewood	8-14-62	9.6	6.8	1.1	100	24	9.5	1.3	105	23	246	7.3
Hohokus Brook at Hohokus	8-14-62	10	17	3.0	111	36	14	4.0	120	29	316	6.8
Saddle River at Lodi	8- 2-62	24	27	3.9	131	45	32	16	157	49	437	7.1
	11-27-62	86	15	2.6	104	45	21	2.1	134	49	370	7.2
Weasel Brook at Clifton	8- 2-62	2.7	13	1.8	110	99	26	13	212	122	481	7.6
Second River at Belleville	8- 2-62	7.8	21	2.9	153	63	44	1.0	204	78	518	7.1
Elizabeth River basin:												
Elizabeth River at Elizabeth	8-28-62	318	12	2.5	63	44	12	4.9	95	44	250	6.5
Rahway River basin:												
Rahway River at Springfield	8-24-62	2.6	14	2.0	116	52	16	6.6	149	54	354	7.0
Rahway River at Rahway	8-29-62	117	6.0	2.5	36	26	8.0	4.2	101	24	153	6.5
Robinsons Branch Rahway River at Rahway	8-29-62	41	10	3.0	54	45	12	2.9	89	44	233	6.7
Wells:												
Edison Township	8- 1-60	----------	12	.9	150	29	13	16	155	32	348	7.4
Menlo Park	7-26-60	----------	12	1.7	97	50	10	3.7	117	38	288	6.7
Park Ridge	4-29-59	----------	17	1.3	96	36	26	6.4	119	41	326	6.6
Port Reading	7-28-60	----------	27	1.1	123	79	13	3.3	144	43	398	6.9
Rahway	2-24-59	----------	12	1.0	150	64	14	3.9	186	63	415	7.6
Woodbridge	7-28-60	----------	12	2.4	0	210	8.5	.3	1[illegible]9	525	525	3.80

Normally the range of dissolved solids also is similar. However, the percentage of bicarbonate ions found in the streams of region 5 (0–20 percent) is lower than that normally found in region 3 (30–50 percent). The chemical quality of streams in the Camden area is affected by industrial and domestic wastes, but most of these wastes are discharged below the head of tide. Thus, although these wastes have little influence on the chemical quality of nontidal parts of streams in region 5, they do influence the quality of water in the tidal reaches and the Delaware estuary. Representative chemical analyses of streams and shallow wells in this region are presented in table 5.

Although the topography of region 6 (fig. 4) is similar to that of region 5, the predominant ions in the streams in this region are sodium, potassium, sulfate, and chloride. Dissolved-solids concentrations normally range from 20 to 60 ppm. This region is the only one in the State in which the predominant cations in the streams are sodium and potassium. Sulfate ions make up the greater percentage of anions, but the percentage of chloride ions increases downstream (toward the southeast) and then exceeds the percentage of sulfate ions. The pH values of stream waters in this region are lower than those in other regions. Representative chemical analyses of streams and shallow wells are presented in table 6.

A comparison of the water-quality map (fig. 4) and the physiographic division map (fig. 5) shows that the chemical character of streams in the Valley and Ridge province and the New England Upland section is predominantly calcium magnesium, bicarbonate; in the Piedmont Lowland section and inner Coastal Plain province, calcium magnesium, sulfate chloride; and in the outer Coastal Plain province, sodium potassium, sulfate chloride. Thus about 60 percent of the State's nearly 8,000 square miles is drained by streams whose predominant chemical constituents are calcium and magnesium. In the conterminous United States, about 87 percent of the streams have this chemical characteristic (Rainwater, 1962).

HARDNESS

Three maps of New Jersey showing the observed range of hardness at low, median, and high streamflow are presented in figure 6. The maps show that streams in the outer Coastal Plain generally exhibit the lowest hardness concentrations in the State—usually less than 80 ppm during low streamflow, less than 50 ppm at median streamflow, and less than 30 ppm during high streamflow. In fact, in the central and southern parts of the outer Coastal Plain, the hardness of water in streams normally does not exceed 25 ppm even during periods of low streamflow. The hardness of the water in streams in the northern

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TABLE 5.—*Representative chemical analyses, in parts per million, of selected streams and wells in region 5 (fig. 4)*

[Analyses by U.S. Geol. Survey]

Location	Date of collection	Mean discharge (cfs)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C.)	pH
									Calcium, magnesium	Noncarbonate		
Raritan River basin:												
Millstone River at Applegarth	3-28-62	22.7	4.8	2.6	2	33	7.9	4.7	36	35	126	4.7
Millstone River at Princeton Junction	3-28-62	----	5.8	2.8	6	34	12	6.0	47	42	147	6.0
South River at Old Bridge	11-29-62	114	3.6	2.3	2	30	7.3	1.3	34	33	121	5.1
Shark River basin:												
Shark River at Glendola	9-8-61	10.1	9.2	----	30	20	10	3.0	42	18	123	6.6
	3-29-62	17.5	----	----	12	----	----	----	33	23	112	7.0
Wreck Pond Brook basin:												
Wreck Pond Brook near Spring Lake	9-8-61	7.97	13	----	23	14	15	3.4	29	10	117	6.5
	3-29-62	11.6	----	----	9	----	----	----	30	23	116	6.6
Manasquan River basin:												
Manasquan River at Squankum	9-28-62	138	8.1	3.0	22	38	11	2.1	54	36	179	6.4
Delaware River basin:												
Assunpink Creek at Trenton	8-27-62	41	17	4.4	31	57	22	18	92	66	308	6.1
Crosswicks Creek at Extonville	8-28-62	282	2.7	3.2	13	17	4.0	6.4	28	18	90	6.2
	11-14-62	130	4.2	2.8	14	21	7.3	5.7	38	26	116	6.2
South Branch Rancocas Creek at Vincentown	8-28-62	519	1.6	2.0	7	9.4	2.5	2.8	17	12	53	5.7
Southwest Branch Rancocas Creek at Medford	3-29-62	57.6	3.0	1.5	5	16	4.5	2.7	20	16	67	5.7
North Branch Rancocas Creek at Pemberton	8-27-62	104	2.1	.4	1	6.9	4.2	.4	10	9	37	4.8
	11-20-62	308	2.1	.8	0	10	4.0	.2	9	9	62	4.5
North Branch Pennsauken Creek at Maple Shade	3-29-62	12.0	6.7	3.8	8	55	14	4.6	67	61	203	6.0
Cooper River at Haddonfield	3-29-62	21.6	10	5.0	13	23	11	11	46	31	166	6.2
Mantua Creek at Pitman	7-24-62	13	3.3	1.8	10	10	6.0	5.2	23	15	75	6.3
Still Run near Mickleton	7-24-62	5.5	4.1	6.9	17	33	12	8.6	59	45	161	6.1
Raccoon Creek near Mullica Hill	3-28-62	17.7	3.0	2.8	8	28	9.6	10	48	42	135	6.1
Salem River at Woodstown	7-24-62	14	5.7	4.8	46	19	16	1.3	63	26	174	6.4
Alloway Creek at Alloway	7-24-62	13	4.5	2.4	22	9.7	12	.4	34	16	102	5.9
	11-21-62	19	4.6	3.0	8	21	13	2.5	34	28	122	5.9

Wells:												
Blackwood	5-28-57	----------	66	7.2	6	3.8	104	118	96	92	623	5.6
Bordentown	4-14-58	----------	2.3	.9	0	10	2.8	.2	8	8	50	4.30
Centre Square	5-29-57	----------	4.8	5.2	1	63	19	48	120	120	339	4.6
Clark's Mills	7-23-57	----------	1.0	1.4	0	8.1	2.9	.0	5	5	40	4.20
Columbus	6-13-61	----------	1.8	3.2	4	21	7.6	.2	30	26	92	5.1
Cranbury	10- 8-58	----------	11	64	44	126	22	123	182	146	643	6.5
Ellisdale	6-13-61	----------	2.5	2.5	108	8.4	3.0	.4	97	9	197	6.8
Elmer	12-10-59	----------	4.0	.4	3	3.7	3.4	1.3	3	1	21	5.2
Georgia	7- 1-58	----------	2.0	1.8	204	1.2	5.0	.2	168	1	333	6.9
Gloucester City	8-31-61	----------	17	6.0	2	110	20	.2	101	100	332	4.7
Hightstown	10- 8-58	----------	8.8	5.0	16	5.0	20	45	58	45	202	6.2
Mickleton	5-28-57	----------	3.5	2.7	12	1.5	13	22	36	26	122	5.9
Pennsauken	8-31-61	----------	7.5	1.5	33	21	8.4	5.8	47	20	141	6.1
Richwood	5-29-57	----------	2.5	1.3	14	.2	5.5	22	28	16	85	6.3
Salem	7-21-59	----------	12	5.5	11	17	33	97	124	115	367	5.5
West Long Branch	7-24-58	----------	11	2.4	7	19	13	9.1	26	21	122	6.2

TABLE 6.—*Representative chemical analyses, in parts per million, of selected streams and wells in region 6 (fig. 4)*

[Analyses by U.S. Geol. Survey]

Location	Date of collection	Mean discharge (cfs)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C.)	pH
									Calcium, magnesium	Noncarbonate		
Metedeconk River basin:												
North Branch Metedeconk River at Lakewood	9-10-59	12.2	5.3	--	14	17	8.0	6.0	34	23	98	6.3
	4-18-60	32.6	6.4	--	10	15	6.0	5.2	22	14	77	6.1
Toms River basin:												
Manapaqua Brook at Lakehurst	5-25-61	9.9	4.4	--	2	8.0	6.0	4.0	12	11	62	4.7
	4-19-60	8.83	3.9	--	2	8.6	3.0	2.5	8	7	46	4.8
Union Branch at Lakehurst	9-8-61	27.7	4.1	--	4	5.0	5.0	1.7	8	5	41	5.3
	3-29-62	52.7	3.9	.8	0	7.4	5.0	.6	6	0	54	4.40
Ridgeway Branch near Lakehurst	9-11-59	16.9	7.4	--	0	16	4.0	5.2	8	8	51	4.30
	4-19-60	44.8	3.0	--	0	9.6	3.0	.9	6	6	46	4.30
Main Branch Toms River at Whitesville	9-11-59	28.6	2.5	--	4	7.5	4.0	2.9	14	11	46	5.6
	4-19-60	70.3	4.6	--	2	15	4.0	2.0	14	13	50	4.8
Oyster Creek basin:												
Oyster Creek near Waretown	9-8-61	26.2	5.3	--	2	4.4	7.0	.4	5	4	31	5.2
	3-28-62	42.3	5.1	--	2	8.0	6.5	.2	8	7	42	5.0
Mill Creek basin:												
Mill Creek near Manahawkin	9-8-61	15.9	4.6	--	3	3.6	5.0	.3	3	1	28	5.4
	3-28-62	21.0	--	--	4	--	--	--	7	4	34	5.9
Mullica River basin:												
Mullica River near Batsto	6-22-60	41	3.5	.5	2	5.9	3.7	1.7	5	4	31	4.7
	6-28-60	32	3.5	.5	2	5.2	3.5	1.6	4	3	27	5.1
	4-17-62	176	1.6	.8	0	9.2	3.6	.5	6	6	50	4.05
Batsto River at Batsto	7-25-62	110	1.6	.8	1	8.6	3.6	.2	11	10	40	4.7
	11-16-62	166	1.7	1.2	0	10	4.1	.3	10	10	55	4.5
Oswego River at Harrisville	7-25-62	68	1.9	1.0	1	6.1	3.9	.4	5	4	40	4.6
	11-16-62	90	2.5	.4	0	9.2	3.5	.2	4	4	52	4.40
Absecon Creek basin:												
Absecon Creek at Absecon	7-25-62	5.9	4.3	.1	2	4.6	7.5	.0	8	7	39	5.3
Great Egg Harbor River basin:												
Great Egg Harbor River at Folsom	7-24-62	76	3.1	.5	2	9.7	4.4	.1	11	10	50	4.8
	11-16-62	93	2.3	1.2	0	10	6.0	1.4	10	10	64	4.5
Tuckahoe River basin:												
Tuckahoe River at Head of River	9-7-61	25.0	--	--	3	5.7	5.0	--	6	4	32	5.3
	3-2[illegible]-62	55.1	2.8	.8	2	5.5	4.1	.4	7	6	35	4.8
Wells:												
Folsom	8-13-57	--	1.6	.4	4	.0	2.6	.4	3	0	31	6.3
Franklinville	6-4-57	--	1.8	.6	26	1.7	3.2	2.5	24	2	60	6.2
Newfield	5-30-57	--	8.6	1.2	3	.2	7.0	22	12	10	88	5.3
Penn State Forest	6-13-61	--	5.0	.5	27	.0	3.6	.2	14	0	55	6.7
Point Pleasant	8-31-61	--	10	2.0	5	11	15	10	17	13	118	5.2
Tabernacle	6-13-61	--	5.6	1.0	8	8.4	9.8	15	28	22	107	5.7

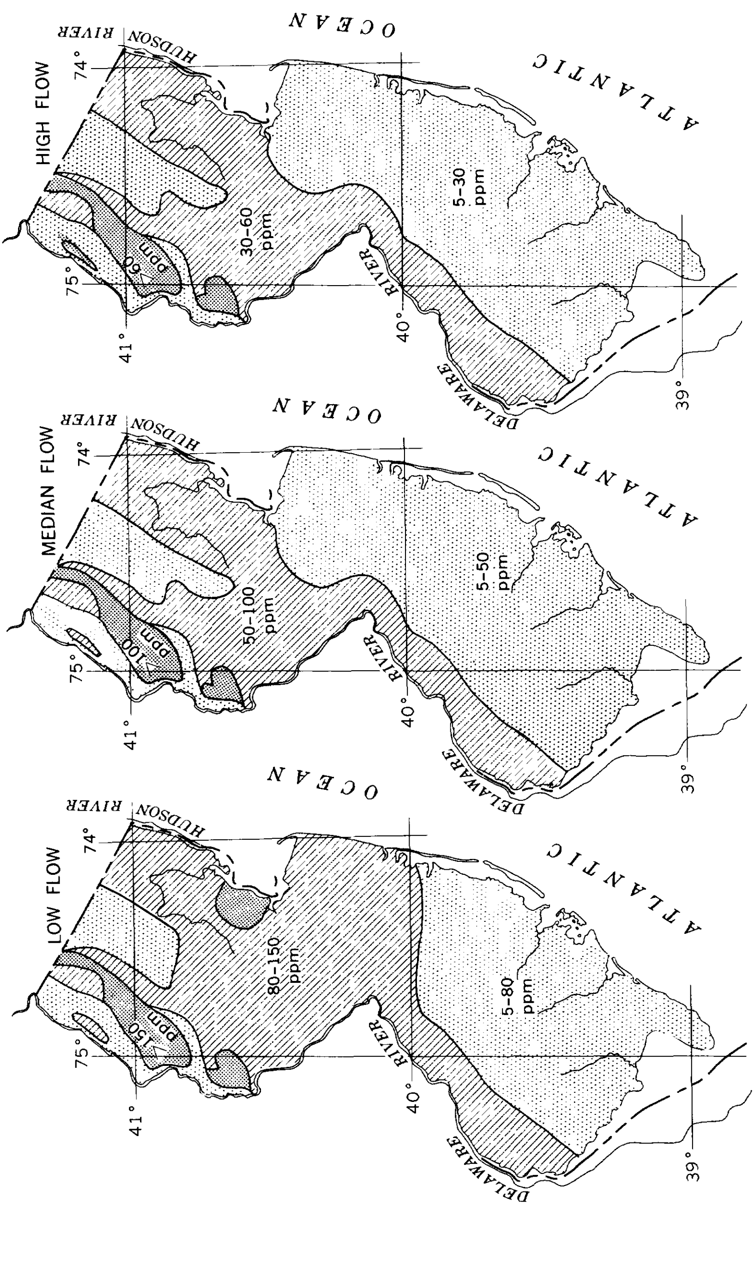

FIGURE 6.—Observed hardness in streams of New Jersey at low, median, and high streamflow conditions.

part of the outer Coastal Plain is greater during periods of low streamflow, varying from 80 to 150 ppm, than the hardness in the central and southern parts, which varies from 5 to 80 ppm during times of low streamflow.

Streams in the inner Coastal Plain, which drain into the Delaware estuary, and those stream draining the Piedmont Lowland section contain slightly harder water than those in the outer Coastal Plain. Hardness of water in these streams usually ranges from 30 to 60 ppm during high streamflow, from 50 to 100 ppm at median streamflow, and from 80 to 150 ppm during low streamflow.

Some streams in the New England Upland and in the Valley and Ridge province contain much harder water, usually exceeding 60 ppm during high streamflow, 100 ppm at median streamflow, and 150 ppm at low streamflow. These are the streams that traverse areas underlain by extensive beds of Cambrian and Ordovician limestone and dolomite. The influence of the very hard (greater than 180 ppm) ground water contributed to streams in these areas is evident from the hardness maps.

Irregularities are also noticeable in hardness characteristics during low-flow conditions in two areas in the Piedmont Lowland section. Streams in the Whippany River basin occasionally exceed the normal (when judged by surrounding basins) hardness of 80 ppm. Likewise, the hardness of water in the Elizabeth and Rahway River basins occasionally exceeds the expected value of 150 ppm. The disposal of lime-treated industrial- and municipal-waste waters into these streams is one possible explanation of these irregularities in hardness.

IRON

Iron concentrations are poorly related to streamflow, but the data suggest that concentrations are higher during low streamflow than during high flow. However, high iron concentrations have been observed at times during periods of storm runoff. Apparently these concentrations include some iron from sediments carried in suspension. This assumption is substantiated by comparison of chemical analyses of duplicate filtered and unfiltered samples. Duplicate samples were collected and analyzed by the Geological Survey at more than 50 gaging stations throughout the State during the summer of 1962. Iron concentrations in unfiltered samples, that is, total iron, were as much as 1.3 ppm higher than in filtered samples. The average reduction of iron by filtration in the duplicate samples was 0.17 ppm.

The observed range of total iron concentration of streams throughout the State during median streamflow is shown in figure 7. In general, the concentrations of total iron in streams draining the

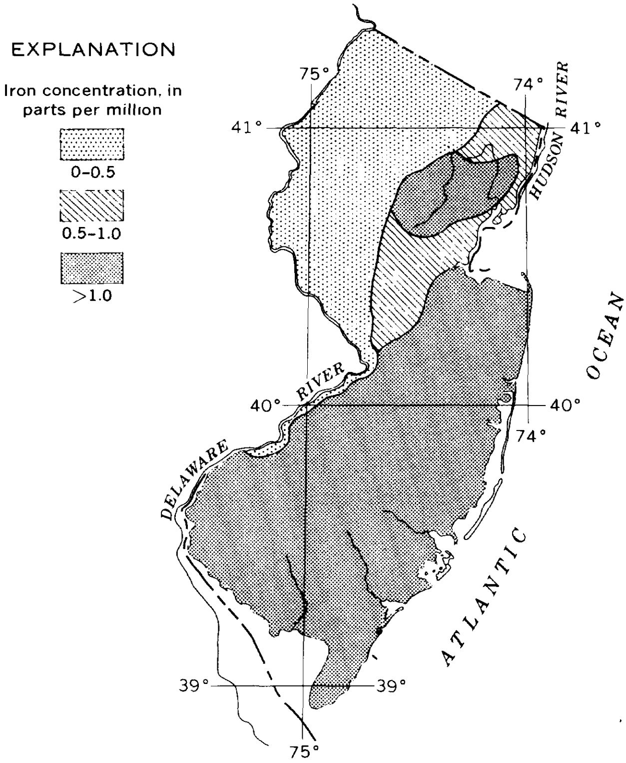

FIGURE 7.—Observed iron concentrations in streams of New Jersey during median streamflow conditions.

Coastal Plain are high, usually more than 1.0 ppm. Analyses of ground water from shallow wells (less than 75 feet in total depth) in the Coastal Plain also indicate high iron concentrations as much as 10 ppm. Ground-water inflow constitutes a large proportion of the total streamflow in this area.

Streams in the Passaic and Hackensack River basins in the glaciated Piedmont Lowland section of northeastern New Jersey also contain high concentrations of total iron, generally more than 1.0 ppm. Streams in both these high-iron-content areas drain wetlands. The vegetal decay and bacterial activity in these wetland areas promote high concentrations of iron in solution. Analyses of ground water in the Passaic and Hackensack River basins show a range from 0.0 to 0.6 ppm of iron. This range suggests that the source of iron in the streams is not predominantly ground water. It may be a combination of waste-water disposal into these streams and vegetal decay.

DETERGENTS

The areal variations in concentration of synthetic detergents in streams throughout the State during periods of low streamflow in 1962 are illustrated on figure 8. The concentrations are measured analytically as apparent alkyl benzene sulfonate (ABS). Data used to prepare this map included ABS analyses by the Geological Survey at more than 50 gaging-station locations and those reported by Dalton and others (1962). These data indicated that most of the water samples contained 0.1 ppm ABS or less. Concentrations at only six of the sampling locations exceeded the 0.5-ppm-ABS maximum recommended by the State Department of Health (1962) for potable-water supply. Figure 8 also shows that the highest concentrations were in the more populated areas in the northeastern part of the State and in the Trenton-Camden areas in the southwest.

In summary, the chemical character of streams in the State is extremely variable from one locality to another. Perhaps the most

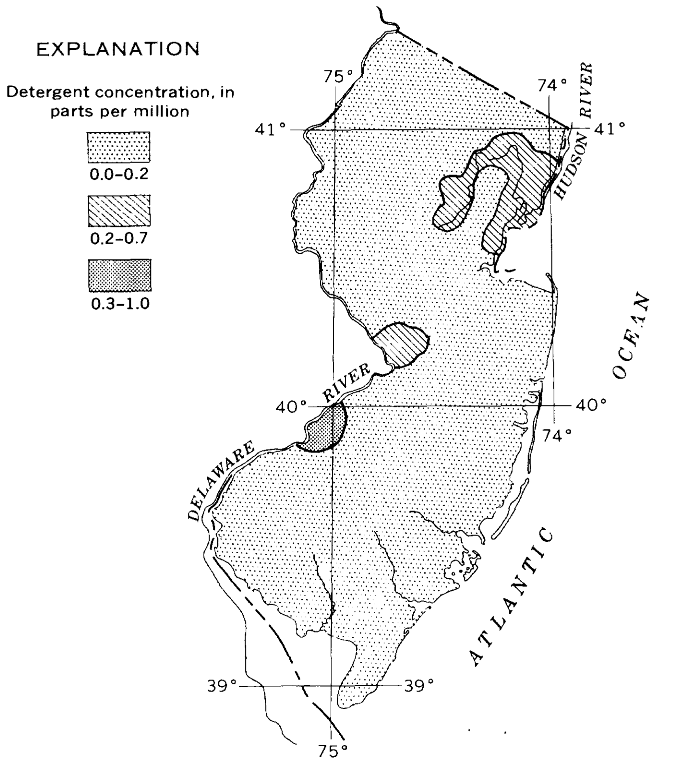

FIGURE 8.—Synthetic-detergent concentrations (ABS) in streams of New Jersey during low-flow conditions, 1962.

important factor influencing this variability is the quality of ground-water inflow. A comparison of figures 4 and 5 readily shows the general relation existing between the physiographic units—and thus the geologic environment underlying a stream—and the prevalent chemical character and dissolved-solids concentration of that stream. Figures 6 and 7 show that this relation exists also with respect to hardness of the water and iron concentration. In addition, the general chemical character of streams in New Jersey may differ from the norm where man has changed the natural regimen of the stream. These manmade changes are illustrated by variances in the normal areal distribution of dissolved solids (fig. 4), hardness (fig. 6), and synthetic detergents (fig. 8) in the more heavily populated areas of the State.

VARIATIONS WITH TIME

The chemical quality of streams in New Jersey has been shown to vary considerably from one region of the State to another. Similarly, it will be shown that water quality at a particular stream location varies considerably with time. In most instances, these variations coincide with environmental changes in the stream regimen, such as seasonal variations in streamflow or air temperature and extended periods of drought or flood.

Five sampling locations for which concurrent data are readily available were chosen for study of the time variations of water quality in various sections of the State. Records used for the Passaic River were provided by the Passaic Valley Water Commission; for the Raritan and Millstone Rivers by the Elizabethtown Water Co.; for the Toms River by the Toms River Chemical Corp.; and for the Delaware River by the Geological Survey (from cooperative studies with the city of Philadelphia and the Commonwealth of Pennsylvania).

MONTHLY VARIATIONS

Monthly variations of dissolved solids, hardness, and streamflow are shown on figure 9. This illustration was developed from a 5-year (1957–61) record of chemical-quality and streamflow data. With the exception of the Toms River, the highest average dissolved solids occur during the July–September period when streamflow is lowest, and the lowest average dissolved solids occur in the March–May period when streamflow is greatest.

Average monthly variations of hardness for the five selected stream locations also are shown on figure 9. As with dissolved-solids concentrations, the monthly fluctuations in hardness usually are related inversely to streamflow. The chemicals that cause hardness make up 40 to 50 percent of the total dissolved solids in these streams.

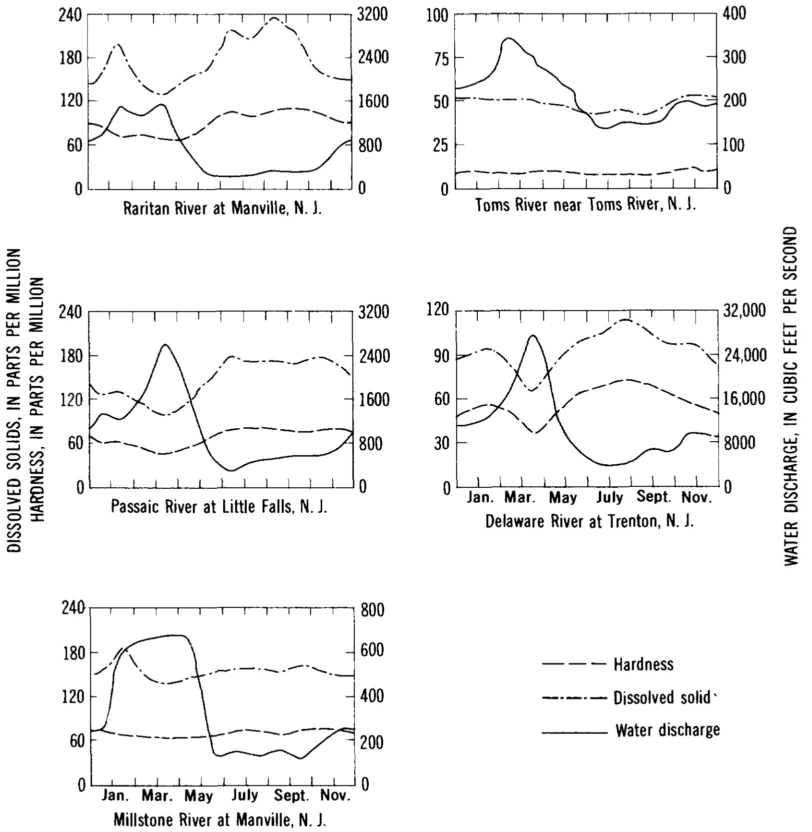

FIGURE 9.—Mean monthly fluctuations of dissolved solids, hardness, and streamflow of the Raritan, Passaic, Millstone, Toms, and Delaware Rivers, 1957–61.

The observed relations between streamflow and chemical constituents, such as those shown on figure 9 for dissolved solids and hardness, are not universal for all parameters. Consider, for instance, the monthly variations of dissolved-oxygen concentration shown on figure 10 for three rivers. The influence of water temperature is quite apparent. Temperatures and several other factors, such as biological activity, dilution, and relative turbulence, exert a more direct control on the oxygen content of a stream than does streamflow.

When expressed as concentration, the illustrated seasonal fluctuations in dissolved oxygen of the three streams appear quite similar. However, for the Raritan River the percent saturation during 1957–61 ranged on the average from about 70 to 99 percent, whereas for the Millstone and Passaic Rivers it ranged from 65 to 95 percent and 55

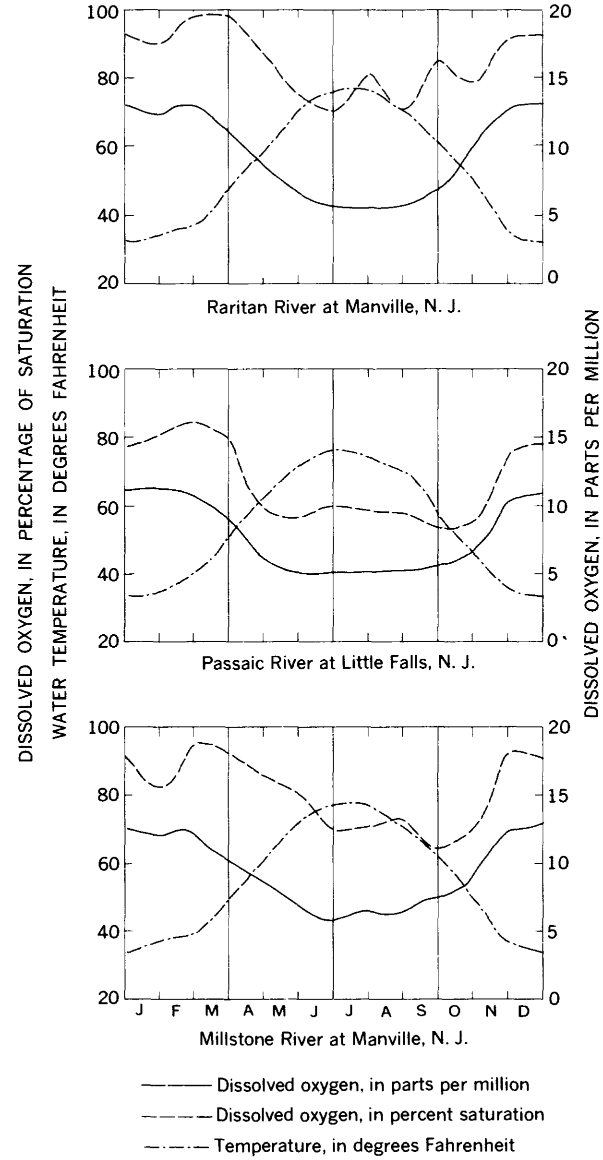

Figure 10.—Mean monthly fluctuations of dissolved oxygen and water temperature of the Raritan, Passaic, and Millstone Rivers, 1957–61.

to 85 percent, respectively. In all three streams the lowest percentages occurred during the late summer and early fall, and the highest during the winter and spring.

Dissolved oxygen, expressed as percent saturation, is often used as an indirect measure of pollution loads because most pollution material is decomposed by bacterial processes and oxygen is essential to maintain these processes at maximum rates. It can be assumed, because the oxygen content of these streams is below 100 percent in all seasons, that the three streams (fig. 10) are receiving pollution loads. However, this assumption is not valid for all streams in the State or even for locations on the streams other than the ones illustrated; only for the three sampling locations from which the data for figure 10 came is the assumption valid.

DAILY VARIATIONS

Natural fluctuations of water quality can be expected for even short periods of time. A 4-day storm-runoff event on the South Branch Raritan River at Stanton in September 1960 illustrates fluctuations such as these (fig. 11). The variation in dissolved-solids concentration was considerable during this 4-day storm-runoff event. A common phenomenon during such an event also is illustrated: The point of maximum dilution, or lowest concentration of dissolved solids, occurs slightly after the runoff peak. After the storm runoff begins to subside and ground-water inflow makes up an increasing part of the total flow in the stream, the dissolved-solids concentration begins to increase.

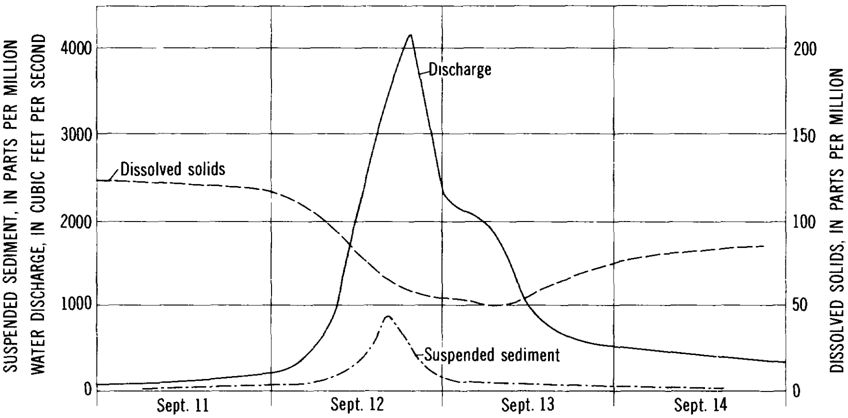

FIGURE 11.—Variations in water quality during a storm runoff, South Branch Raritan River at Stanton, N.J., September 11–14, 1960.

LONG-TERM VARIATIONS

Relations between water quality and streamflow also can be used to determine the existence, and perhaps the magnitude, of any long-term trend that may exist now or may have existed in the past, as well as daily, monthly, annual, or seasonal variations. Consider the variations shown by a 2-year moving average of dissolved-solids concentration and streamflow of the Delaware River at Trenton, N.J., during the 15-year period 1947–61, as presented on figure 12. A comparison of streamflow and dissolved-solids data in this figure shows that there was a slight trend toward lower quantities of water and slightly higher dissolved-solids concentrations during the periods plotted. Streamflow for the first 8 years (1945–52), however, was approximately 15 percent above the long-term average (50 years) at this site. Consequently, dissolved-solids concentrations for the first 8 years were probably lower than the 50-year average, if no change is assumed in the relation between dissolved solids and streamflow. The average flow during 1953–61 was very close to the 50-year average, and the dissolved-solids data for this period may represent the actual average dissolved-solids concentration.

McCarthy and Keighton (1964) recently showed, using double-mass curve analyses, that a greater load of dissolved solids was being transported past Trenton per unit volume of water after 1953 than before. The ratio of tons of dissolved solids to streamflow was shown to be constant from 1944 to 1953. From 1953 to 1961 a greater load of dissolved solids per volume of water was reported. The rate of transport prior to 1953 was reported as approximately 0.104 ton of dissolved solids per million gallons of water. Subsequent to 1953, it increased about 11 percent to 0.116 ton per million gallons.

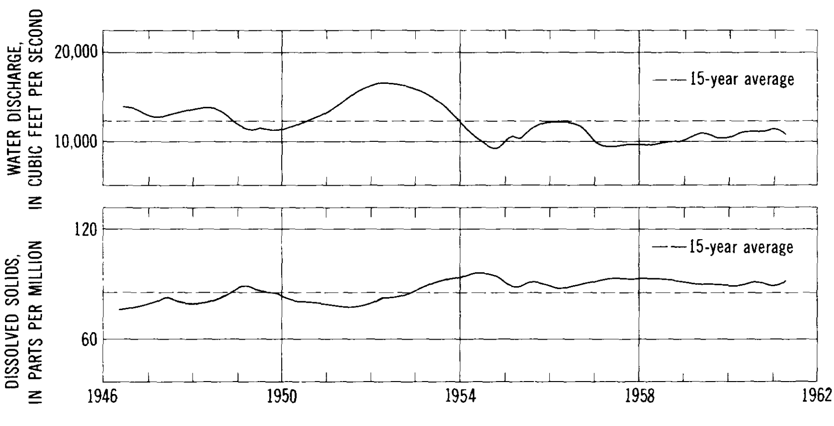

FIGURE 12.—Annual fluctuation of dissolved-solids concentration and streamflow, Delaware River at Trenton, N.J., 1947–61.

With the advent of the nuclear age, the amount of radioactive substances in man's environment has increased. Radioactivity can originate either from natural sources or from artificially induced sources, such as fallout from nuclear-weapons testing and wastes arising from the peaceful uses of radioactive materials.

The variations of gross beta activity in water samples from New Jersey's streams are plotted on figure 13. This illustration is based on the average values of quarterly measurement at more than 125 locations sampled by the State Department of Health during 1958–63 (Aaroe, 1963). Two peaks, one in the spring of 1959 and one in the spring of 1963, followed closely after large-scale nuclear-weapons tests in the atmosphere.

Thus, the chemical quality of a stream varies with time as well as with area. Generally, these changes with time are related to the amount of water flowing in the stream. An awareness of the variations between streamflow and quality can often be of great assistance to a water manager or user.

PHYSICAL QUALITY

Physical properties and measures of suspended materials are considered in this report as the primary physical-quality characteristics of water. The significance of these physical-quality features depends largely upon the intended use of the water. Consider, for instance, water temperature. The cooling capacity of water in a stream is reduced considerably by an increase in temperature. Drastic changes

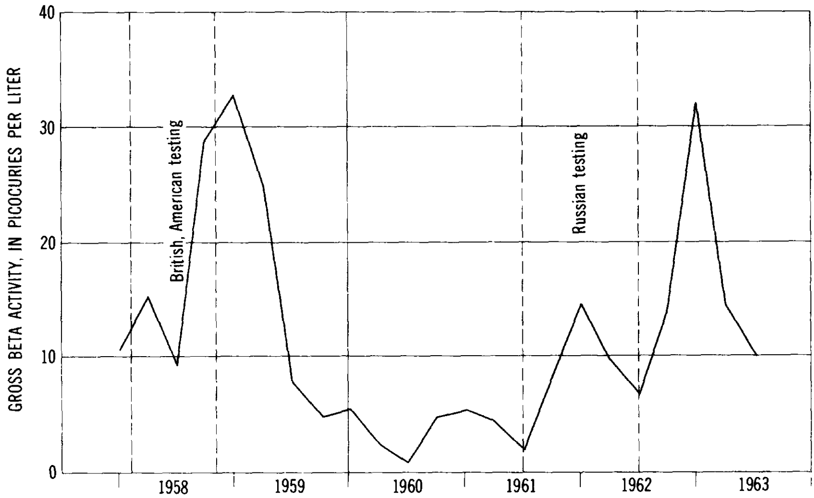

FIGURE 13.—Quarterly average gross beta activity in streams of New Jersey, 1958–63.

in the temperature of a stream often may be detrimental to aquatic life. Variations in water temperature also can affect some chemical- and bacterial-quality parameters. As water temperature increases, there is a corresponding decrease in the solubility of oxygen in the water (fig. 10). If, for example, a stream were saturated with oxygen at 37°F, the water would contain about 13.5 ppm of dissolved oxygen. At 77°F, this water would contain about 8.5 ppm. Water temperature also influences biological activity. During periods of low stream temperatures the activity is reduced, and during high temperatures it is increased (fig. 19).

Variations in the suspended-sediment concentration also influence the potential use of a stream. If a stream is used as a water-supply source, large settling basins are often necessary to remove fine sediments. Furthermore, deposition of sediments may reduce the desirability of a stream, lake, or reservoir for recreation, particularly where deposition produces shallow water and, ultimately, excessive weed growth. Relatively high concentrations of suspended sediment in a stream reduce the amount of light available to the stream-bottom biota. If this condition continues for a long time, a sequence of changes in aquatic life may result. Furthermore, deposition of stream-transported sediment at the mouth of a river or in an estuary presents an additional problem by filling in navigation channels with unwanted materials that require expensive removal.

Most available data on water temperature and suspended sediment in New Jersey streams suggest that neither presents an extensive problem in the State. However, expected increases in water use for cooling and continued soil exposure owing to urban expansion require the careful attention of land and water managers, who wish to avoid future physical-quality problems.

WATER TEMPERATURE

Natural stream temperatures are controlled largely by air temperature, solar radiation, and ground-water inflow.

At the three stream locations for which data are shown in figure 10, maximum water temperatures occur during July and August and minimum temperatures occur in December, January, and February. Maximum and minimum air temperatures in the State also occur during these same periods (U.S. Weather Bureau, 1963). On the basis of scattered stream-temperature data collected for these three and for other streams in the State, it can safely be assumed that stream temperatures vary directly with those of air but the daily variations in stream temperatures are less than those of air.

The influence of the sun on stream temperatures can be seen by examining the frequency of occurrence of mean daily temperatures of five streams (fig. 14). Note that the occurrence of higher temperatures coincides with larger drainage areas. The temperature of the Delaware River at Trenton (drainage area, 6,780 sq mi) exceeds 70°F approximately 25 percent of the time, whereas the Great Egg Harbor River at Folsom (drainage area, 56.3 sq mi) exceeds this temperature only 1 percent of the time.

The longer time of exposure to solar radiation on longer stream courses is the reason for the increase on temperature as drainage area increases. Of course, the relative stream width and shading effect of nearby hills and vegetation should also be considered in any discussion of the variation of temperature with drainage area. Because of the shade from adjacent trees and brush, the water surface of a stream having a small drainage area usually receives considerably less solar radiation than that of a larger stream. Streams draining small areas are also narrower than streams draining larger areas, and the amount of water surface available to solar radiation is correspondingly less. Thus, the amount of solar radiation is a significant factor in governing the temperature of a stream.

The influence of ground-water inflow on stream temperature can also be seen on figure 14. Collins (1925) observed that shallow ground waters (20 to 200 feet in depth) in the United States have fairly uni-

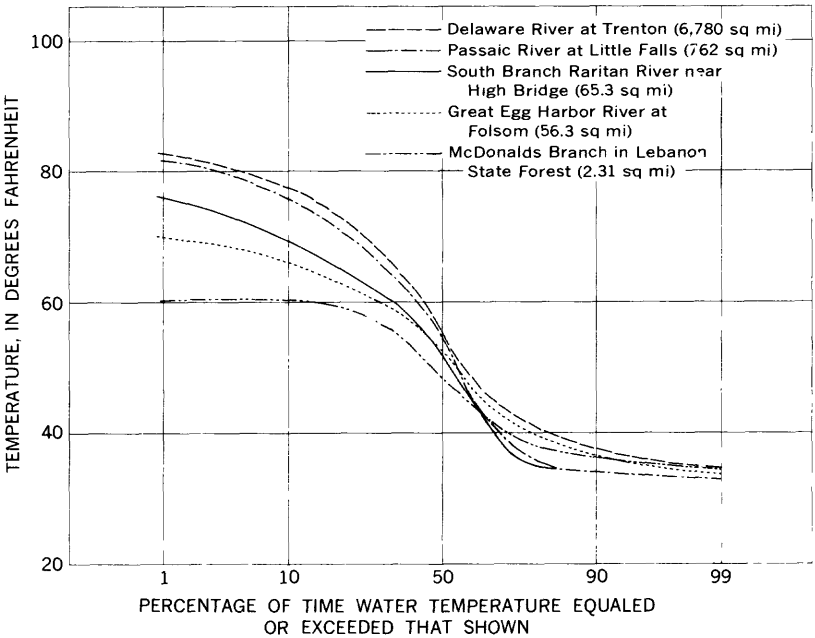

FIGURE 14.—Frequency of occurrence of mean daily water temperatures for five streams in New Jersey.

form temperatures ranging from 3° to 6°F above the mean annual air temperature. In New Jersey, ground water that reaches a stream will range from approximately 50°F in the north to about 60°F in the south. As mentioned previously, the flow in streams draining the Coastal Plain is predominantly from ground-water sources. Furthermore, streams in the Coastal Plain are usually small in both width and drainage area and consequently solar radiation has little effect on the temperature of these streams. The major influence on the temperature of these streams should therefore be that of the ground-water inflow. Two streams, Great Egg Harbor River and McDonalds Branch, shown on figure 14, drain the Coastal Plain. In both streams the water temperature rarely exceeds 70°F even during periods of extremely high air temperature; thus can be seen the major influence that ground-water temperatures have on these streams.

Figure 14 also shows that the median (50 percent) temperature of streams illustrated closely approximates the estimated temperature of ground-water inflow and ranges from 48° to 56°F. The range of water temperatures below the median is very narrow because of the limiting freezing temperature of 32°F. The freezing temperature is approached more rapidly by water in the smaller streams than in the larger.

STREAM SEDIMENTATION

Several environmental factors control soil erosion and the delivery of suspended solids to New Jersey streams. The more significant variables include physical characteristics of the soils, land slope, land use or vegetal cover, extent of precipitation and direct runoff, and capacity of the surface drainage system to transport fine sediments in suspension.

In the glaciated New England Upland and in the Valley and Ridge province (fig. 5), erosion rates and, consequently, suspended-sediment concentrations in streams are comparatively low. Poor surface drainage characteristics, which were developed in part by Pleistocene glaciation, combine with rather dense vegetal cover to produce comparatively low yields of sediment to local streams.

Generally, in the Piedmont Lowland section and in the unglaciated New England Upland, an abundance of silt and clay-size sediments in the soils, moderate land slope, and less vegetal cover produce the highest sediment yields found in the State. Typical streams draining the Piedmont lowlands often remain slightly turbid for relatively long periods after direct runoff has taken place.

The southern two-thirds, or Coastal Plain province, of New Jersey contains soils having an unusually high permeability. Sandy soils, gentle surface slopes, and generally dense vegetal cover inhibit erosion-producing overland runoff. Porous soils in this part of the State have a great capability for permitting rainfall to infiltrate rather than to run off. Without the transport media usually provided by overland runoff, relatively little sediment reaches the surface-drainage system.

An estimate of the range in annual sediment yield from each physiographic area (fig. 5) is given in the following table:

Physiographic area	*Estimated sediment yield, in tons per square mile*
Valley and Ridge	25–100
New England Upland	10–100
Piedmont Lowland	75–500
Outer Coastal Plain	10–40
Inner Coastal Plain	50–150

These estimates were made after an appraisal of recent stream-sedimentation data collected in New Jersey and adjacent states. The ranges of estimated annual yield are based on normal use of the land in each physiographic area.

The transport rate of suspended sediment and, to a lesser degree, the concentration of suspended solids in New Jersey's streams are related to streamflow. A high water discharge usually is preceded by overland runoff that delivers eroded sediments to the stream system. A typical change in suspended-sediment concentration during a runoff event for a sampling site on the South Branch Raritan River is shown by the curve in figure 11. As shown in this figure, the suspended-sediment concentration of a stream can be influenced during a storm-runoff event and for a considerable time after it. The actual length of time is dependent upon the size of the drainage area and upon the amount of type of sediment being contributed.

A significant relationship exists between sediment discharge and water discharge for most New Jersey streams. The relation between daily sediment load and streamflow for four streams in New Jersey is illustrated in figure 15. The steep slope of the sediment-transport curves in figure 15 shows that the rate of sediment discharge changes rapidly with small changes in streamflow. For most streams in New Jersey, sediment discharge increases approximately as a second-power function of water discharge. Limited data for Great Egg Harbor River, however, suggest that a different relation exists for Coastal Plain streams that carry little or no direct runoff and, consequently, do not receive the large amounts of sediment normally associated with overland runoff.

Long-term variation of sediment discharge in New Jersey streams depends largely upon streamflow and upon the relative exposure of

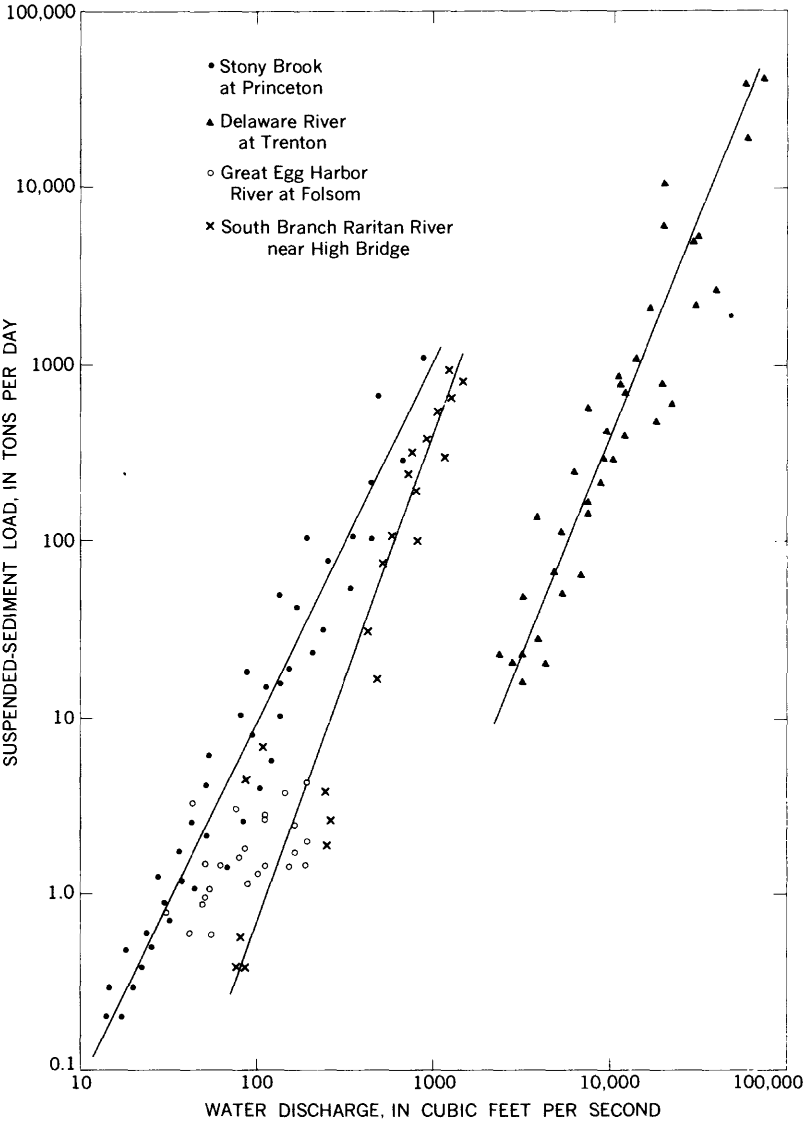

FIGURE 15.—Relation of daily sediment load to streamflow for four streams in New Jersey.

soils to erosive rainfall and runoff. Seasonal changes in sediment discharge commonly follow similar fluctuations in streamflow. Runoff in the early spring, for example, delivers a large percentage of the annual sediment load to the stream systems. The types of exposure of soils to erosion also can influence stream sedimentation rates. For example, Guy (1957) found a trend toward decreasing sediment yields from the Brandywine Creek basin in Pennsylvania and Delaware during the period 1947–55. Soil conservationists infer from these data that intensive application of conservation practices on the farmland in this basin caused a reduction in sediment yields. George (1963) found that urban expansion and reservoir construction in the Stony Brook basin in New Jersey produced higher than average sediment yields from that basin between 1956 and 1959. The inference is that changes in land use that expose soils to erosion often create temporary sources for excessive stream sedimentation. Changing land-use patterns throughout the State are expected to continue altering the sedimentation characteristics of its streams.

TURBIDITY

Although detailed measurements of the suspended-sediment transport characteristics of New Jersey streams are available for only a few locations, a great deal of information is available on stream turbidity. Turbidity, a measure of the ability of water either to transmit or to reflect light, is not a quantitative measure of the amount of suspended solids in water. However, if the suspended solids are primarily mineral and rock fragments rather than organic

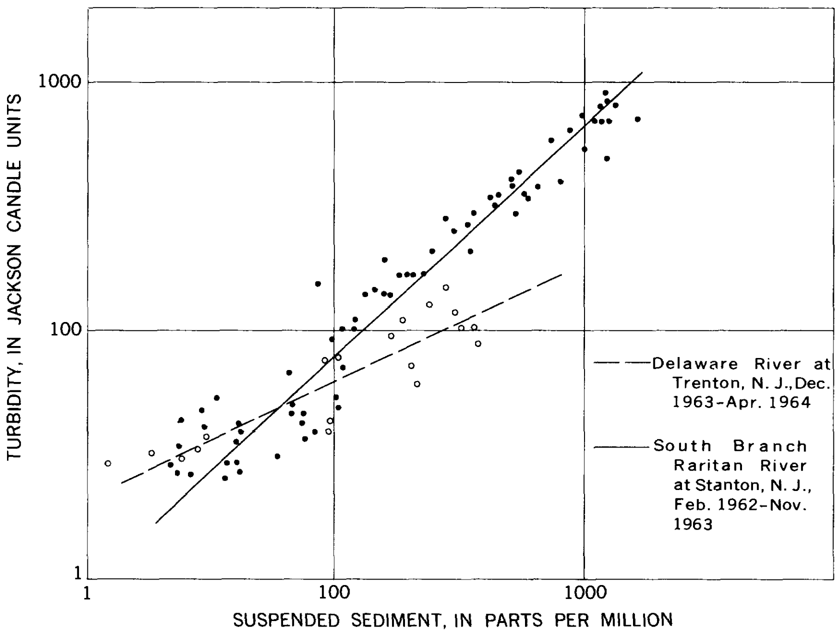

Figure 16.—Relation of turbidity to suspended-sediment concentration for Delaware River at Trenton (○) and South Branch Raritan River at Stanton (●).

materials and if the particle size of the suspended sediments is predominantly finer than sand (0.062 mm), judicious appraisal of the relation between turbidity and sediment concentration may provide a good approximation of the suspended-sediment concentration in a stream.

Recent studies of the relationship between turbidity and sediment concentration in two of New Jersey's streams (fig. 16) indicate that during median to high streamflow, when a large part of the stream sediments are in transport, a significant relationship exists between the two parameters. During low flow, when turbidity is due more to the presence of organic material—algae and other microscopic plants—the relationship is less reliable.

Random turbidity data collected by the New Jersey Department of Health have been evaluated to develop a qualitative view of regional variation in stream turbidity. Median turbidity values, in Jackson candle units (Jcu), for samples from more than 100 stream-sampling locations were plotted to produce the areal variation shown on figure 17. This composite of data illustrates, indirectly, several turbidity-

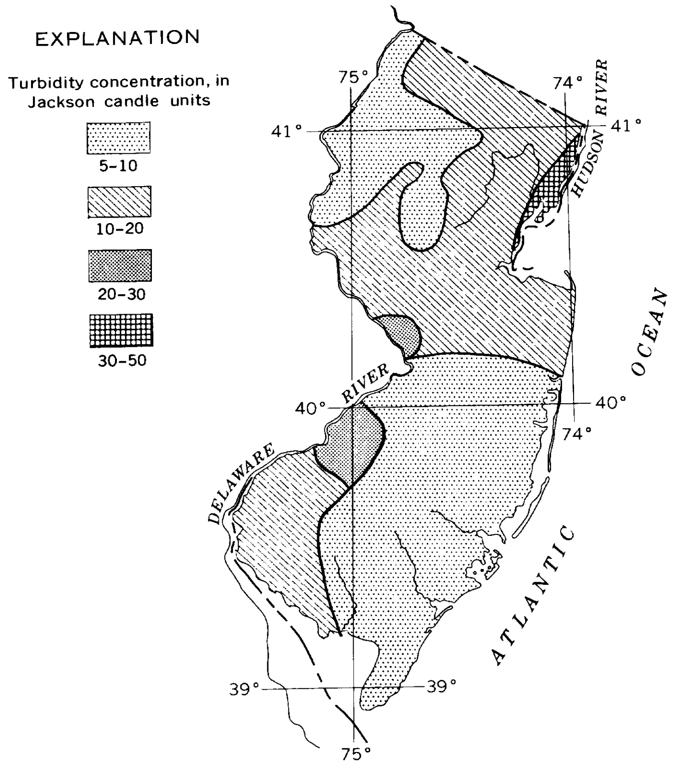

FIGURE 17.—Observed range in median turbidity of New Jersey streams.

producing conditions throughout the State. In the northeast and in the vicinity of Camden and Trenton, high turbidity probably is caused by stream sedimentation from urbanization and by industrial and municipal wastes. A more natural producer of high turbidity is found in streams draining the Piedmont Lowland and New England Upland sections. Here the soils contain an abundance of clay and silt. Normal erosion of these fine sediments makes the local streams highly turbid. The data indicate that average turbidities are lowest in the southern and northwestern parts of the State. Low erosion rates here apparently limit the quantity of turbidity-producing sediment that reaches the streams.

BACTERIAL QUALITY

Much basic information is available on the amount of coliform bacteria in the streams of New Jersey. Coliform-bacteria counts are a common measure of the safety of water for drinking, bathing,

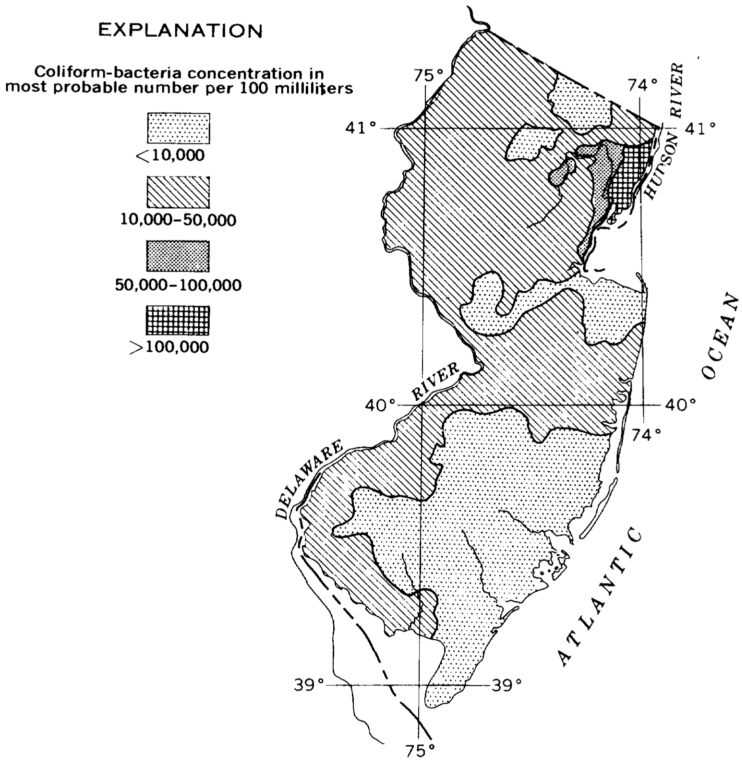

FIGURE 18.—Extreme coliform-bacteria counts in streams in New Jersey, 1958–62.

and growing shellfish. These bacterial data are collected by the State Department of Health, for its Stream Pollution Control and Shellfish Programs, and by almost all public-water suppliers.

Areal variations of coliform-bacteria counts are illustrated on figure 18. The map was drawn by grouping average values of the three highest figures recorded during the 5-year period 1958–62. The highest counts of coliform bacteria (more than 50,000 mpn) are found in the metropolitan area adjacent to New York City and can be attributed largely to municipal and industrial pollution. Large counts (10,000–50,000 mpn) are found also in the State's farming areas. Soil bacteria that are drained from farmlands into the nearby streams by surface runoff are probably responsible for these large counts.

Coliform-bacteria counts do not correlate with streamflow, but they are related to water temperature. The mean daily count and water temperature for the Raritan River at Manville during 1961 are presented on figure 19. These data were obtained from the Elizabethtown Water Co. Note that the coliform-bacteria count increases as the water temperature rises.

Detailed analyses of the concentration and frequency of the occurrence of different species of micro-organisms in water are not within the scope of this report. Such information is available on request from the State Department of Health, the U.S. Public Health Serv-

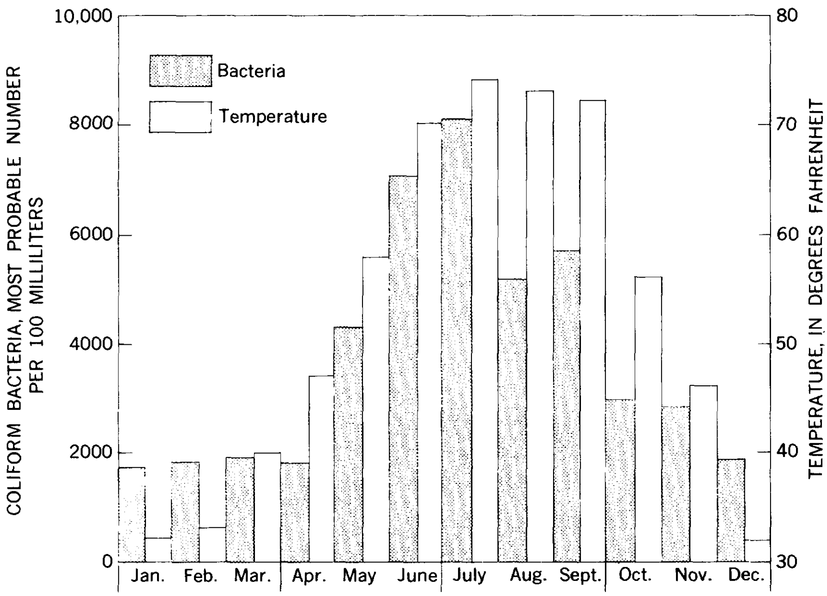

FIGURE 19.—Mean monthly coliform-bacteria count and water temperature, Raritan River at Manville, N.J., 1961.

ice, or, in some cases, the local board of health in the vicinity of a given stream or lake.

SUMMARY

The quality of the water of streams in New Jersey is quite variable. Under natural conditions, changes in quality are caused by the variable quality of the individual components (precipitation, direct overland runoff, and ground-water inflow) that make up the flow in the stream.

Normally, an inverse relation exists between chemical-quality parameters and streamflow. During extreme high-flow conditions the concentration of dissolved constituents in a stream approximates that of the principal streamflow component, surface runoff, and is usually at a minimum. During extreme low-flow conditions it approximates, or is similar to, that of the ground-water inflow. Normally, concentrations are at a maximum during low-flow periods because the ground-water inflow usually contains more dissolved solids than surface runoff, owing to longer duration of contact with soluble materials. Under natural conditions the dissolved solids in times of intermediate streamflow are a composite having the quality of both the ground-water inflow and the direct overland runoff and are regulated by the amount of streamflow contributed by each.

However, a direct relation between dissolved solids and streamflow occurs in several streams draining the outer Coastal Plain. In this area, concentrations of dissolved solids reaching the streams from ground-water sources are extremely low, whereas flushing from the numerous swamps and marshlands during spring higher flows may contain more concentrated waters. Thus, an increase of dissolved solids occurs with an increase in flow in these streams.

The natural quality of water of many streams in New Jersey has been changed by manmade changes in the natural regimen of the drainage basin. Streams draining the highly industrial and urban areas in the northeastern part of the State and in the vicinity of Trenton and Camden reflect the influence of waste discharges. The highest concentrations of dissolved solids (130–450 ppm), hardness of water (80–300 ppm), synthetic detergent (0.2–1.0 ppm), turbidity (30–50 Jcu), and coliform bacteria (more than 50,000 mpn) are found in streams draining these areas. Streams that receive drainage from farmlands in central New Jersey also tend to have high turbidity (10–20 Jcu) and coliform-bacteria counts (10,000–50,000 mpn).

In addition, the lower reaches of many streams in the State are influenced by tides. The chemical character of water in these reaches, especially the chloride and dissolved-solids content, is extremely variable because of tidal invasions of salt water. The effects of these invasions on the quality of an estuary are dependent upon the distance from the ocean, fresh-water inflow, range and stage of tide, and climatological conditions.

Approximately 60 percent of the State's area is drained by streams that contain calcium and magnesium as the predominant cations. The remainder are predominantly sodium potassium waters.

Streams in the Valley and Ridge province are predominant in calcium, magnesium, sulfate, and bicarbonate ions. The virtual lack of solutes in glacial-drift deposits and the high runoff rates in this province produce some of the lowest dissolved-solids concentrations (30–90 ppm) in the State's streams. Ion concentrations in these streams rarely exceed 0.5 ppm; hardness of water, 80 ppm; turbidity, 10 Jcu; and coliform bacteria, 50,000 mpn, except during extreme low-flow conditions.

The New England Upland section is drained by streams that are predominant in calcium, magnesium, and bicarbonate ions. Many streams in this section drain areas underlain by extensive beds of Cambrian and Ordovician limestone and dolomite. Dissolved-solids concentrations in streams of this section range from 90 to 250 ppm, the higher concentrations occurring in streams that traverse the limestone and dolomite deposits. Normally, the highest hardness of water in the State is found in streams in this section, often exceeding 150 ppm. Iron concentrations rarely exceed 0.5 ppm; turbidity, 20 Jcu; and coliform bacteria, 50,000 mpn, except during low streamflows.

Streams draining the Piedmont Lowland section normally are predominant in calcium, magnesium, and sulfate ions. The dissolved-solids concentrations in these streams usually range from 40 to 120 ppm. However, streams draining the Precambrian rocks and glacial materials in the northern part of the province are usually lower in dissolved solids, their range being from 40 to 100 ppm, than streams in the southern part. Hardness of water in these streams usually does not exceed 150 ppm; turbidity, 20 Jcu; and coliform bacteria, 50,000 mpn, except during low-flow periods. Iron concentrations are variable, the highest concentrations being about 1.0 ppm.

Although they drain parts of the Piedmont Lowland section, many streams in the northeastern part of the State exhibit an altogether different chemical character. These streams drain the highly industrialized and populated metropolitan area adjacent to New York City. They contain a much higher percentage composition of chloride and nitrate ions than other streams in the Piedmont Lowland section. In fact, the highest concentrations of dissolved solids (130–450 ppm),

Dalton, Thomas, F., O'Leary, John D., and Ciuba, Stanley J., 1962, Problems of detergents in water supplies, with emphasis on New Jersey streams: Am. Water Works Assoc., Proc. New Jersey Sec., 18 p.

Durfor, Charles N., and Anderson, Peter W., 1963, Chemical quality of surface waters in Pennsylvania: U.S. Geol. Survey Water-Supply Paper 1619–W, 50 p.

Durfor, Charles N., and Keighton, W. B., 1954, Chemical characteristics of Delaware River water, Trenton, New Jersey, to Marcus Hook, Pennsylvania: U.S. Geol. Survey Water-Supply Paper 1262, 173 p.

George, John R., 1963, Sedimentation in the Stony Brook basin, New Jersey, 1956–59: U.S. Geol. Survey open-file rept., 67 p.

George, John R., and Anderson, Peter W., 1963, Water-quality studies of New Jersey streams: New Jersey Dept. of Health Public Health News, v. 44, no. 6, p. 154–159.

Guy, H. P., 1957, The trend of suspended-sediment discharge of the Brandywine Creek at Wilmington, Del., 1947–55: U.S. Geol. Survey open-file rept., 55 p.

Keighton, W. B., 1965, Delaware River water quality, Bristol to Marcus Hook, Pennsylvania, August 1949 to December 1963: U.S. Geol. Survey Water-Supply Paper 1809–O, 57 p.

Love, S. K., 1950, Water quality in the Middle Atlantic States: Am. Water Works Assoc. Jour., v. 42, p. 257–265.

——— 1961, Relationship of impoundment to water quality: Am. Water Works Assoc. Jour., v. 53, p. 559–568.

McCarthy, Leo T., Jr., and Keighton, Walter B., 1964, Quality of Delaware River water at Trenton, New Jersey: U.S. Geol. Survey Water-Supply Paper 1779–X, 50 p.

McCartney, David, and Beamer, Norman H., 1962, Continuous recording of water quality of the Delaware estuary: Am. Water Works Assoc. Jour., v. 54, p. 1193–1200.

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

New Jersey State Department of Health, 1962, Potable water standards: State of New Jersey, 4 p.

Rainwater, F. H., 1962, Stream composition of the conterminous United States: U.S. Geol. Survey Hydrol. Inv. Atlas HA–61, 3 p.

Rogers, Franklyn C., 1955, Engineering soil survey of New Jersey: Rutgers Univ. Eng. Research Bull. 15, Rept. 1, 114 p.

U.S. Weather Bureau, 1963, Decennial census of United States climate—monthly averages for State climatic divisions, New Jersey: Climatography of the U.S. No. 85–24, 2 p.

Vermeule, Cornelius C., 1894, Report on water-supply, water-power, the flow of streams and attendant phenomena: New Jersey Geol. Survey, v. 3, 450 p.

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