Water-Supply and Irrigation Paper No. 106 Series { M, General Hydrographic Investigations, 12
0, Underground Waters, 26 }

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

WATER RESOURCES

OF THE

PHILADELPHIA DISTRICT

BY

FLORENCE BASCOM

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

The publications of the United States Geological Survey consist of (1) Annual Reports; (2) Monographs; (3) Professional Papers; (4) Bulletins; (5) Mineral Resources; (6) Water-Supply and Irrigation Papers; (7) Topographic Atlas of United States, folios and separate sheets thereof; (8) Geologic Atlas of United States, folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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WS 71. Irrigation systems of Texas, by T. U. Taylor. 1902. 137 pp., 9 pls.
WS 74. Water resources of the State of Colorado, by A. L. Fellows. 1903. 151 pp., 14 pls.
WS 87. Irrigation in India (second edition), by H. M. Wilson. 1903. 238 pp., 27 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. 361 pp.

The following papers also relate especially to irrigation: Irrigation in India, by H. M. Wilson, in Twelfth Annual, Pt. II; two papers on irrigation engineering, by H. M. Wilson, in Thirteenth Annual, Pt. III.

SERIES J—WATER STORAGE.

WS 33. Storage of water on Gila River, Arizona, by J. B. Lippincott. 1900. 98 pp., 33 pls.
WS 40. The Austin dam, by T. U. Taylor. 1900. 51 pp., 16 pls.
WS 45. Water storage on Cache Creek, California, by A. E. Chandler. 1901. 48 pp., 10 pls.
WS 46. Physical characteristics of Kern River, California, by F. H. Olmsted, and Reconnaissance of Yuba River, California, by Marsden Manson. 1901. 57 pp., 8 pls.
WS 58. Storage of water on Kings River, California, by J. B. Lippincott. 1902. 100 pp., 32 pls.
WS 68. Water storage in Truckee Basin, California-Nevada, by L. H. Taylor. 1902. 90 pp., 8 pls.
WS 73. Water storage on Salt River, Arizona, by A. P. Davis. 1902. 54 pp., 25 pls.
WS 86. Storage reservoirs on Stony Creek, California, by Burt Cole. 1903. 62 pp., 16 pls.
WS 89. Water resources of Salinas Valley California, by Homer Hamlin. 1903. 91 pp., 12 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. 361 pp.

The following paper also should be noted under this heading: Reservoirs for irrigation, by J. D. Schuyler, in Eighteenth Annual, Pt IV.

[Continued on third page of cover.]

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Department of the Interior,
United States Geological Survey,
Hydrographic Branch,
Washington, D. C., March 2, 1904.

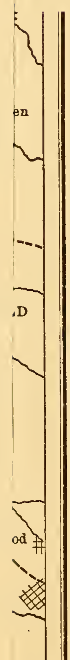
Sir: I have the honor to transmit herewith the manuscript for a paper entitled "Water Resources of the Philadelphia District," prepared by Dr. F. Bascom at the request of Mr. M. L. Fuller, chief of the eastern section of the division of hydrology. The work was conducted in connection with investigations for the geologic branch of the Survey, through the courtesy of which the report has been prepared.

The paper presents a summary of the knowledge of the water resources of Philadelphia and vicinity, including both surface and underground waters. In the discussion of the former a considerable number of data which have appeared in scattered and inaccessible publications are brought together and presented with the new material. The facts relating to underground waters are largely new and are the result of a personal canvass of the region.

Very respectfully,

F. H. Newell,
Chief Engineer.

Hon. Charles D. Walcott,
Director United States Geological Survey.



WATER RESOURCES OF THE PHILADELPHIA DISTRICT.

By Florence Bascom.

INTRODUCTION.

The area included in the Philadelphia district lies between 39° 45′ and 40° 15′ north latitude and 75° and 75° 30′ west longitude. It has a length of 34.50 miles from north to south and a width of 26.53 miles from east to west, and covers one-fourth of a square degree, which is equivalent, in that latitude, to about 915.25 square miles. It is mapped on the Germantown, Norristown, Philadelphia, and Chester atlas sheets of the United States Geological Survey.[a] Each of these sheets represents a tract fifteen minutes in extent each way. This district is in Pennsylvania, New Jersey, and Delaware, and comprises, in whole or in part, ten counties—Bucks, Montgomery, Philadelphia, Delaware, and Chester counties in Pennsylvania; Burlington, Camden, Gloucester, and Salem counties in New Jersey; and Newcastle County in Delaware. A population of nearly 2,000,000 is embraced within these limits. The location and general relations of the district are shown in fig. 1, on the next page.

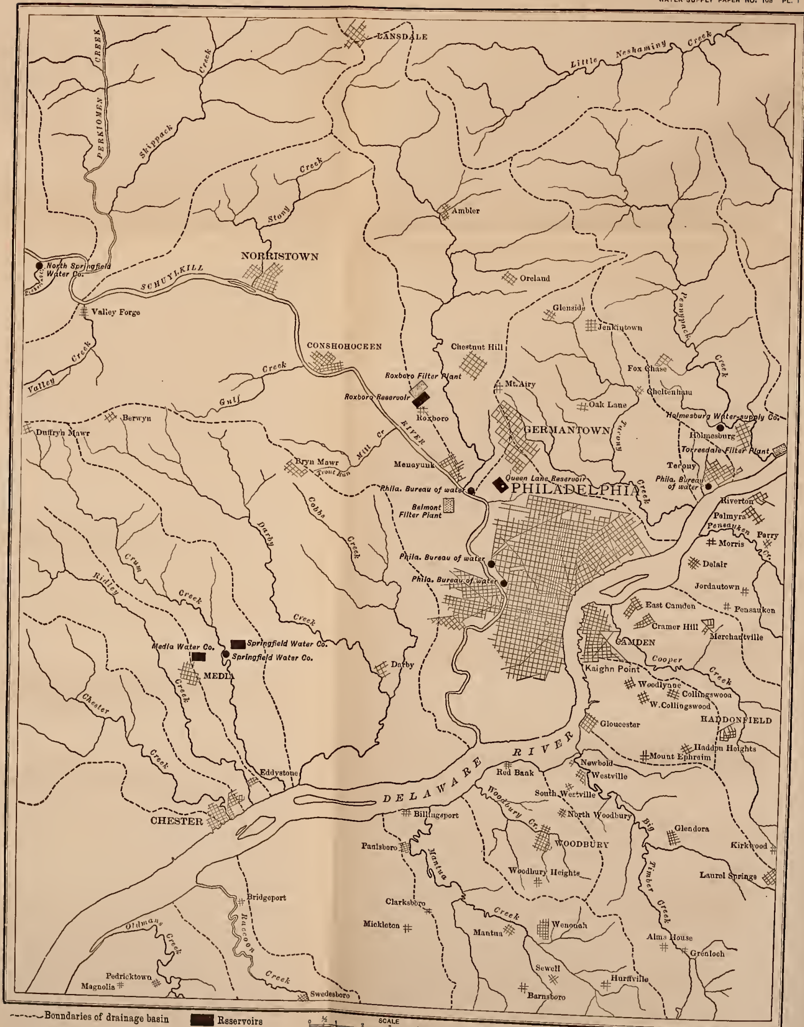
In this paper will be discussed the topography, rainfall, run-off, and stream discharges of the chief hydrographic basins, the geology and water-bearing horizons, and the water power and water supply in relation to its present and future utilization.

ACKNOWLEDGMENTS.

Data for the report on the present utilization of the water supply have been obtained chiefly from Mr. J. W. Ledoux, chief engineer of the American Pipe Manufacturing Company, and from Mr. John E. Codman, chief draftsman of the Philadelphia bureau of water. These gentlemen have courteously furnished me all the desired data in their possession, both published and unpublished. It is a pleasure to acknowledge my obligations to them and to Mr. John W. Hill, chief engineer of the Philadelphia bureau of filtration.

Stream measurements, rainfall data, and stream discharges have been taken from records made and published by Mr. Codman.

[a] These four sheets have been combined and published as a map of Philadelphia and vicinity.



------ Boundaries of drainage basin ▬ Reservoirs SCALE 0 ½ 1 2 3 4 5 6 MILES Filter beds ● Pumping stations

SKETCH MAP OF PHILADELPHIA DISTRICT.

A number of tables, plates, and records have been extracted from the reports of the Philadelphia bureaus of filtration and of water.

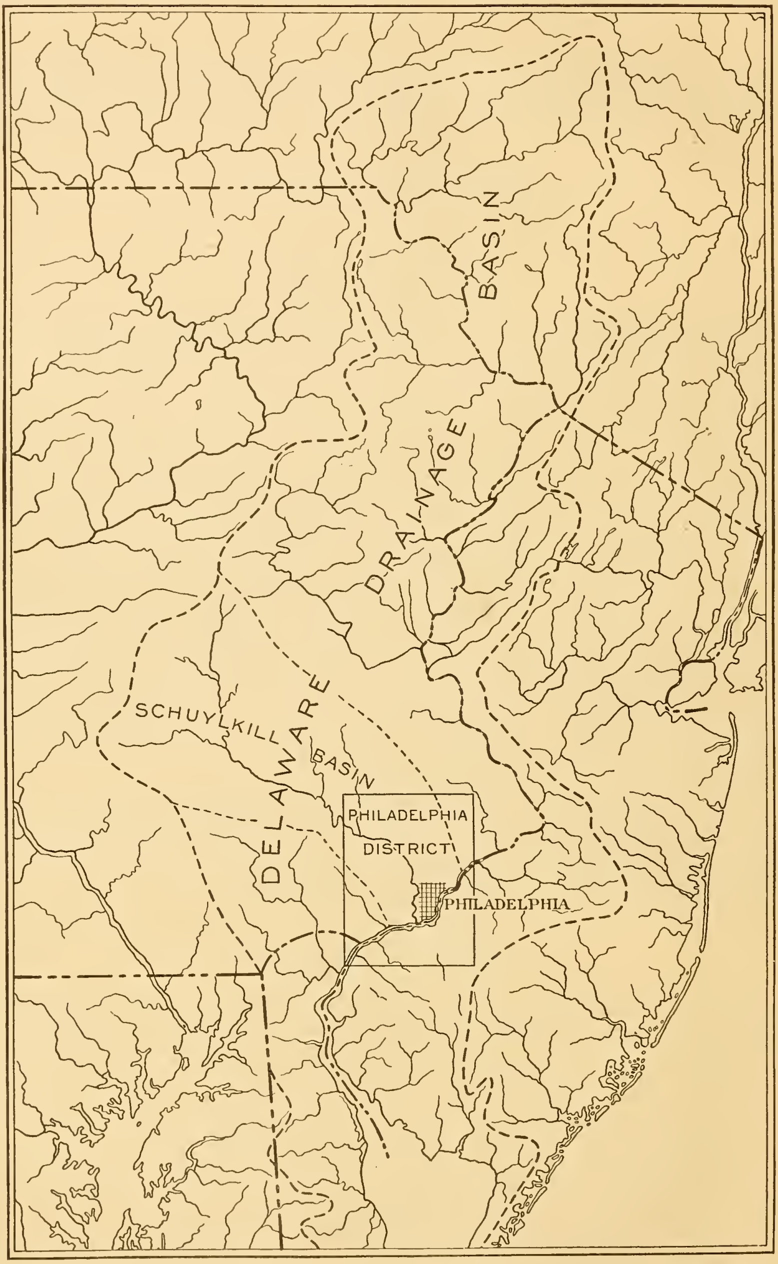


FIG. 1.—Index map showing location of Philadelphia district and limits of Delaware and Schuylkill drainage basins.

Much material has also been obtained from the reports of the geological survey of New Jersey, especially volume 3; from Bulletin

No. 138 of the United States Geological Survey, by N. H. Darton; from papers by Prof. Oscar C. S. Carter, and from a Report on the New Red, by Mr. Benjamin Smith Lyman.

I wish also to acknowledge the courtesy of water-supply companies not represented in the above list, and of artesian well owners, who have promptly furnished the information desired of them.

GEOLOGY.

PHYSIOGRAPHY.

The Atlantic border region is divisible into three very unlike physiographic provinces—the Appalachian district, the Piedmont Plateau, and the Coastal Plain. The Piedmont Plateau constitutes about three-fourths of the Philadelphia district and the Coastal Plain the remaining fourth. The Delaware River marks the boundary between the two provinces, which are distinct hydrographically.

Each of these provinces has a history, which is, in a broad way, the same for the entire province. This accounts for the uniformity of physiographic features in a single province.

Piedmont Plateau.—This plateau lies on the southeastern foot of the Appalachian system—whence its name Piedmont—and is separated from the Atlantic Ocean by a belt of coastal plain 10 to 100 miles in width. Its western limit is defined by the Highlands of New Jersey in New Jersey, by the South Mountain in Pennsylvania, and by the Blue Ridge in Virginia.

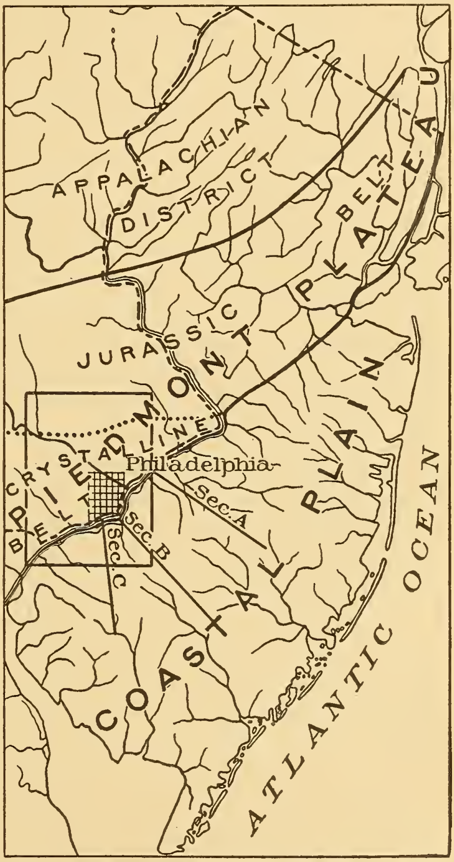


Fig. 2.—Sketch map showing physiographic divisions.

The Piedmont Plateau has an average width of 50 miles and extends north and south from Maine to Alabama. A conspicuous change in topography marks its eastern boundary, where it passes into the Coastal Plain. Along this border line are situated the large cities of the Atlantic States—New York, Trenton, Philadelphia, Baltimore, Washington, Richmond, Petersburg, Raleigh, Augusta, and Macon. Eastward the streams open into tidal estuaries and afford good shipping facilities, while westward they cease to be navigable and flow in tumultuous courses.

The plateau is an upland of moderate elevation with shallow valleys and with some eminences rising above its general level. The hills reach a height of 1,600 feet, while the upland varies from 200 to 600 feet above sea level. If the valleys were filled in, the upland would be converted into a flat elevated plain; hence the term plateau has been applied to it. This plateau slopes eastward and southeastward toward the sea. Neither the heterogeneous constitution nor the complex structure of the underlying rocks is revealed in the level lines of the plateau. The larger streams which cut into it and converted it into a diversified upland flowed in courses which were independent of the structure and of the character of the rock floor. This diversified upland or dissected plateau is further characterized by the absence of bare rock ledges and by the presence of a thick mantle of fertile soil comparatively free from stones.

The streams of the Piedmont Plateau are of two classes—(1) those which rise west of the plateau and (2) those which rise within it. Streams rising west of the plateau usually empty into estuaries which head at its junction with the Coastal Plain; of this class are the Delaware and Schuylkill of the Philadelphia district, and the Susquehanna, Potomac, and James to the south. Streams which rise within the plateau either are wholly within it, emptying into estuaries or larger streams, as Cobbs, Darby, Ridley, and Chester creeks, or cross both the plateau and the Coastal Plain, flowing directly into the ocean, as the Roanoke and Savannah rivers.

The highest land of the Philadelphia Piedmont district is in the vicinity of Valley Forge, in the Schuylkill watershed, where the quartzite hills have an altitude of 640 feet.

North of these hills and of a line extending N. 70° E. the underlying rocks are shales with interbedded sandstone. These formations have a fairly uniform and very gentle dip 8° to 15° N. or NW. They diminish to a thin edge to the southeast and reach a thickness of 15,000 feet to the northwest. They cover about one-third of the Piedmont district, giving rise to low relief and furnishing a fine, red, somewhat calcareous clay soil which is fairly fertile. The remaining two-thirds of the district is underlain by a series of quartzites, limestones, schists, gneisses, granites, gabbro, and serpentine. This series has been subjected to a pressure which has produced a conspicuous schistosity dipping steeply southeast, and a more gentle but often steep inclination of the bedding planes southeast or northwest. These formations occur in belts trending northeast and southwest, roughly parallel to the Delaware River. Through differential erosion they give rise to a more diversified topography than the comparatively uniform shale formations. They furnish a deep, rich, clayey soil.

Coastal Plain.—The Coastal Plain lies between the sea and the Piedmont Plateau and extends from Staten Island southward to Florida, varying in width from 10 to 150 miles. It slopes gently seaward and rises westward to a height of a few hundred feet. It is a low, flat area composed of beds of unconsolidated gravel, sand, clay, and marls, which have an inclination corresponding, in the main, with the general seaward slope of the plain. The drainage is largely simple, the streams being consequent upon the uplift of the plain from the sea. Streams rise also in the Piedmont Plateau or in the Appalachian district and cross the Coastal Plain. In the part of the Coastal Plain included in the Philadelphia district all the streams are simple.

STRATIGRAPHY.

The rock floor of the Philadelphia district is composed of a complex of ancient metamorphosed sedimentary formations and crystalline igneous intrusives.

This floor is overlain in the southeastern third of the district by unconsolidated materials—gravels, sands, clays, and marls of Cretaceous, Tertiary, and Quaternary age. These materials are chiefly confined to the Coastal Plain and are discussed under the heading, "Coastal Plain."

ANCIENT CRYSTALLINE ROCKS.

The ancient crystalline rock floor, which is overlain in the Coastal Plain to the southeast by Cretaceous, Tertiary, and Quaternary gravels, sands, clays, and marls and on the northeast by the Triassic shales and sandstones, is uncovered in the larger half of the Piedmont Plateau which constitutes the central portion of the Philadelphia district.

The formations of this complex are of pre-Paleozoic and Paleozoic age, and their sequence and character are, briefly, as follows:

ALGONKIAN.

Baltimore gneiss (*Fordham gneiss of New York folio*) (*pre-Georgian*).—This formation is a hard, light-colored, feldspathic, banded rock, which marks the crest of Buck Ridge. Into it have been intruded granitic and gabbroitic igneous masses.

CAMBRIAN.

Chickies quartzite (*Georgian*).—This is a crystalline, sericitic, itacolumitic quartzite, which outcrops in the north Chester Valley, Cold Point, and Whitemarsh hills, Camp Hill, and Edge Hill.

CAMBRO-ORDOVICIAN.

Chester Valley limestone.—The Chester Valley limestone is a crystalline, magnesian, siliceous, blue or white limestone, chiefly confined to Chester Valley.

ORDOVICIAN.

Wissahickon mica-gneiss and mica-schist (*Hudson*).—This is a crystalline bedded formation which, like all this series, outcrops in a belt trending northeast and southwest. The mica-gneiss extends from the Delaware River to Chestnut Hill. Toward the north this formation becomes a mica-schist, which forms the south Chester Valley hills and immediately overlies the Chester Valley limestone.

TOPOGRAPHIC FEATURES OF CRYSTALLINE AREA.

The more basic peripheries of the gabbro masses have been altered to serpentine and steatite and have given rise to low sterile ridges. A rolling lowland characterizes the easily eroded mica-gneiss, while the quartzitic mica-schist forms ridges.

A fertile, open valley characterizes the limestone, while the resisting quartzite forms the highest and most abrupt hills of the Piedmont belt.

The Baltimore gneiss and the gabbro which completely and irregularly penetrates it constitute the broad, flat-topped ridge (Buck Ridge) which extends across the district in a northeast-southwest direction and separates the Wissahickon gneiss belt from the other sedimentaries. These formations are folded in synclines and anticlines overturned to the northwest. This structure gives them a prevailing dip to the southeast. The dip is sometimes coincident with, but often less steep than, a marked cleavage to the southeast. Huntington and Cream valleys—the narrow lowland on the northwest base of Buck Ridge—probably mark a fault heading northwest. This fault has caused the disappearance along this line sometimes of the limestone, sometimes of the quartzite, and sometimes of both formations.

The pressure from the southeast, which has caused the overturned folds, the cleavage, and the faulting, has affected igneous and sedimentary materials alike, completely metamorphosing the entire series and producing like secondary structures in all.

SEDIMENTARY ROCKS.

TRIASSIC.

In the northern third of the district the ancient crystalline floor is overlain by gently dipping shales with interbedded sandstones.

These formations are intermediate in age between the eroded floor, upon which they were laid down, and the Coastal Plain formations on the southeast. They belong to the Triassic period and are represented, within the Philadelphia district, by five divisions.[a]

Norristown shale.—The lowest division, the Norristown shale, immediately overlies the crystallines and is exposed in a belt, about 4 miles in width, extending northeast and southwest from Valley Forge

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[a] Lyman, B. S., Report on the New Red of Bucks and Montgomery counties: Second Geol. Survey Pennsylvania, Final report, vol. 3, pt. 2, pp. 2589-2638.

and Norristown to the Delaware River. Within this division are included about 6,100 feet of red, partly calcareous shales, with some important though comparatively thin beds of brown sandstone near the top and several thicker and coarser beds of hard, gray, pebbly sandstone at the base.

In the Philadelphia district the Norristown shale dips gently to the northwest. This is also true of the overlying formations; hence they outcrop at the surfaces successively to the northwest in belts which are, in general, parallel to the Norristown shale belt.

Gwynedd shale.—This is the next overlying formation and includes approximately 3,500 feet of usually dark-red, sometimes dark-green or dark-gray, and partly black shales with traces of coal.

These shales are comparatively hard and form the ridge north of Norristown which trends northeast. The Gwynedd shale is exposed in a belt about 3 miles wide.

Lansdale shale.—Overlying the Gwynedd shale is the Lansdale formation, which embraces 4,700 feet of red calcareous shales, with a few scattered green layers and a few thin red sandstone beds. This formation is soft, and forms the lowland belt, 4 miles wide, northwest of the Gwynedd ridge.

Perkasie shale.—These shales cross the northwest corner of the district in a belt about 1 mile wide. They have a thickness of approximately 2,000 feet, and are hard, green, red, or gray shales, with some carbonaceous layers. Because of their hardness these shales mark high land.

Pottstown shale.—A triangular area in the extreme northwest corner is covered by the Pottstown shale. This formation consists chiefly of soft, red, calcareous shales, with a few thin limestone beds, and has a total thickness of 10,700 feet. Flat, low-lying land characterizes the Pottstown shale area.[a]

RAINFALL.

Records of the rainfall in Philadelphia have been kept by the United States Weather Bureau since 1872. The table on pages 17–21 is based on the figures of that Bureau.

The total rainfall has been calculated for each period of the water year from 1872 to 1904. These figures, as is to be expected, show that the average monthly precipitation on the Middle Atlantic coast is nearly uniform throughout the year. It is somewhat greater during the growing period[b] than in any other period of the year. The aver-

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[a] Mr. N. H. Darton, who has made a recent (1904) survey of the Triassic series of this district, groups the members of the series in three divisions—the Stockton formation, which corresponds approximately to the Norristown shale; the Locatong formation, which contains the Gwynedd shale; and the Brunswick shale, which embraces the Lansdale, Perkasie, and Pottstown shales.

[b] As regards rainfall and run-off records, Rafter has divided the year into three periods—those of storage, growing, and replenishing—with a water year beginning December 1. The storage period extends from December 1 to May 31, although at times it may begin November 1 and end with April. The growing period extends from June to August, inclusive, and the replenishing period from September to November, inclusive. See Water-Sup. and Irr. Paper No. 80, U. S. Geol. Survey, 1903, pp. 16-17.

age monthly precipitation during the storage and replenishing periods is very nearly the same.

It will be shown that the run-off of the streams is absolutely and proportionally greater in the storage period than in the replenishing period, and least of all in the growing period, when the rainfall is greatest.

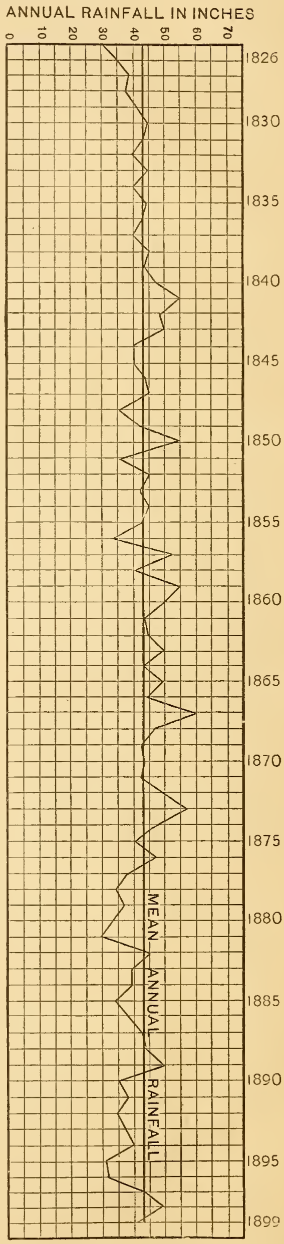


FIG. 3.—Diagram showing rainfall at Philadelphia, 1825-1900.

The minimum annual rainfall in the thirty-two years covered by the record was 30.21 inches, in 1881, which is 9.98 inches less than the normal. The maximum annual rainfall occurred in 1873; it was 55.28 inches, or 15.09 inches above the normal. The mean annual rainfall in the thirty-two years since 1872, or the normal for Philadelphia, is 40.57 inches. This is not a high average precipitation for a temperate region. For sixteen years out of the thirty-two the annual rainfall was less than 40 inches.

The rainfall at the principal eastern cities in 1902, as given in the United States Weather Bureau Report, was as follows:

Rainfall in principal eastern cities in 1902.

	Inches.
Portland, Me	45.18
Boston	44.96
New Haven	47.91
New York	44.80
Philadelphia	39.84
Baltimore	43.95
Washington	43.46

To what degree this relatively low figure for the normal precipitation in Philadelphia represents the actual facts, and to what degree the recorded difference in precipitation at Philadelphia and Baltimore may be due to unavoidable inaccuracies consequent upon the location and exposure of rain gages as suggested by the similarity in the topographic conditions at those two cities, is a matter for future investigation.

Rainfall, in inches, at Philadelphia, 1872–1903.[a]

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1871–72.			
December–May	-------		
June–August	21.30		
September–November	12.29		
1872	-------	48.36	+ 8.17
1872–73.			
December–May	24.72		
June–August	17.39		
September–November	14.53		
1873	-------	55.28	+15.09
1873–74.			
December–May	23.09		
June–August	10.86		
September–November	11.20		
1874	-------	46.25	+ 6.06
1874–75.			
December–May	15.80		
June–August	14.18		
September–November	9.35		
1875	-------	40.22	+ .03
1875–76.			
December–May	23.24		
June–August	8.98		
September–November	17.14		
1876	-------	47.39	+ 7.20
1876–77.			
December–May	12.02		
June–August	11.41		
September–November	14.40		
1877	-------	37.26	− 2.93
1877–78.			
December–May	15.14		
June–August	11.84		
September–November	5.19		
1878	-------	34.53	− 5.66

[a] Based on tables given in reports of Weather Bureau, 1896-1903, with additional data for 1903.

Rainfall, in inches, at Philadelphia, 1872–1903—Continued.

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1878–79.			
December–May	14.82		
June–August	17.52		
September–November	2.91		
1879		36.75	− 3.44
1879–80.			
December–May	15.13		
June–August	14.50		
September–November	4.59		
1880		33.58	− 6.61
1880–81.			
December–May	19.62		
June–August	6.01		
September–November	6.00		
1881		30.21	− 9.98
1881–82.			
December–May	22.17		
June–August	9.67		
September–November	14.40		
1882		45.58	+ 5.39
1882–83.			
December–May	17.51		
June–August	11.09		
September–November	9.78		
1883		39.17	− 1.02
1883–84.			
December–May	23.64		
June–August	11.13		
September–November	4.05		
1884		39.34	− .85
1884–85.			
December–May	16.16		
June–August	9.93		
September–November	7.85		
1885		33.35	− 6.66
1885–86.			
December–May	21.55		
June–August	8.47		

Rainfall, in inches, at Philadelphia, 1872–1903—Continued.

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1885–86.			
September–November	7.00		
1886		37.24	− 2.95
1886–87.			
December–May	15.96		
June–August	16.26		
September–November	7.98		
1887		42.17	+ 1.98
1887–88.			
December–May	22.91		
June–August	10.33		
September–November	12.73		
1888		44.06	+ 3.86
1888–89.			
December–May	18.97		
June–August	18.75		
September–November	15.18		
1889		50.60	+10.41
1889–90.			
December–May	15.92		
June–August	8.69		
September–November	7.93		
1890		34.02	− 6.17
1890–91.			
December–May	19.19		
June–August	11.38		
September–November	6.17		
1891		38.19	− 2.37
1891–92.			
December–May	20.71		
June–August	7.69		
September–November	8.07		
1892		34.78	− 5.89
1892–93.			
December–May	19.48		
June–August	7.54		
September–November	9.59		
1893		37.65	− 2.91

Rainfall, in inches, at Philadelphia, 1872–1903—Continued.

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1893–94.			
December–May	21.88		
June–August	4.53		
September–November	13.03		
1894		40.34	− .22
1894–95.			
December–May	20.41		
June–August	6.97		
September–November	5.90		
1895		31.01	− 9.55
1895–96.			
December–May	17.77		
June–August	7.80		
September–November	7.34		
1896		32.15	− 6.42
1896–97.			
December–May	15.53		
June–August	15.75		
September–November	7.24		
1897		42.04	+ 2.59
1897–98.			
December–May	22.24		
June–August	14.44		
September–November	13.86		
1898		49.23	+ 9.03
1898–99.			
December–May	23.23		
June–August	10.96		
September–November	7.57		
1899		39.96	− .44
1899–1900.			
December–May	17.64		
June–August	9.54		
September–November	12.73		
1900		40.91	+ .49
1900–1901.			
December–May	17.95		
June–August	15.45		

Rainfall, in inches, at Philadelphia, 1872–1903—Continued.

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1900–1901.			
September–November	7.83		
1901		45.54	+ 5.56
1901–2.			
December–May	24.25		
June–August	11.93		
September–November	13.67		
1902		49.76	+ 9.92
1902–3.			
December–May	22.75		
June–August	14.79		
September–November	7.20		
1903		41.50	+ 1.44
Mean precipitation for 32 years:			
December–May	19.40		
June–August	11.78	40.57	
September–November	9.55		

STREAMS.

PIEDMONT HYDROGRAPHIC BASIN.

The Piedmont Plateau (see fig. 2, p. 11) is crossed by the Schuylkill River and limited on the southeast by the Delaware River. The other watercourses are tributary to one or the other of these two streams. The valley of the Delaware is not more than 20 feet above sea level, while the divide between the Delaware and the Schuylkill rises to a height of 520 feet.

DELAWARE RIVER.

The Delaware River has a total length of 410 miles (fig. 2), but only 35 miles are included in the Philadelphia district (Pl. I). It is navigable by ocean steamers to Philadelphia, 100 miles from its mouth, and there is a low-water depth of 5 feet to Trenton, 30 miles northeast of Philadelphia. It is tidal to this point, 130 miles above the capes. Above Trenton it has an average fall of about 6.7 feet per mile. Its drainage area, including all its branches, is 12,012 square miles. The population and the classification of land on the different portions of the Delaware watershed, as computed by the New Jersey survey,[a] are as follows:

Population and classification of lands in Delaware watershed.

	Population per square mile.	Improved lands.	Barrens.	Forest.
		Per cent.	*Per cent.*	*Per cent.*
Above Water Gap	31	34	7	59
Above Easton	43	39	6	55
Above Trenton	98	43	6	51
Lehigh River	415	48	5	47

The Delaware is subject to considerable seasonal fluctuation in volume. Its stages have been summarized by Mansfield Merriman, as follows:[b] "January, frozen and medium height; February and March, breaking up and high; April, May, and June, high; July, subsiding; August and September, low; October, low but subject to high freshets; November, low, often very low; December, rising a little and freezing." The conditions favorable to floods are common to the district—a heavy rainfall on frozen ground or a rainfall in excess of what the ground is able to absorb. The estimated flow of the Delaware above Trenton is given in the table on the next page, taken from volume 3 of the report of the New Jersey geological survey.

As a source of domestic supply and power the Delaware is extremely important. It has been utilized for domestic supply to a large degree, but the increasing impurity of its water necessitates an elaborate system of filtration, such as is now being operated at Torresdale by the city of Philadelphia. With adequate filtration the Delaware can supply the increasing population near it with abundant water. In 1894 it supplied in New Jersey 142,636 inhabitants with 17,010,464 gallons of water daily. The estimated supply for Trenton without storage was 601,600,000 gallons. Analysis of the water shows that above Trenton the Delaware is polluted with sewage and industrial refuse to a dangerous degree.

The water power of the Delaware has been largely left unutilized, probably because of the difficulty of building dams and the comparative cheapness of fuel. The number of mills on the Delaware above Trenton is only 186, with a net horsepower of 6,658. The New Jersey survey estimates that there is 3,576 horsepower available during nine months of the year at Trenton unused.

[a] Geol. Survey New Jersey, vol. 3, p. 231.

[b] Ann. Rept. Chief of Engineers for 1873, Appendix U, p. 19.

Estimated flow of Delaware River above Trenton.[a]

	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
AVERAGE YEAR.													
Inches of rainfall	3.67	3.57	3.40	3.67	3.57	3.99	3.99	4.17	4.52	3.67	3.40	3.67	45.29
Inches flowing off	2.97	3.01	2.83	2.92	2.48	1.74	1.26	.90	.87	1.10	1.92	2.75	24.75
Flow in 1,000 gallons daily per square mile	1,660	1,680	1,695	1,640	1,440	975	730	505	487	670	1,070	1,590	1,180
Horsepower on 1 foot fall per square mile	0.292	0.297	0.298	0.288	0.253	0.181	0.128	0.089	0.086	0.112	0.189	0.280	0.207
ORDINARY DRY YEAR.													
Inches of rainfall	3.95	4.04	1.67	2.95	2.60	3.36	3.73	4.47	3.93	0.99	2.09	2.22	36.00
Inches flowing off	3.23	3.45	1.25	2.28	1.76	1.37	1.04	.87	.80	.60	.52	.69	17.86
Flow in 1,000 gallons daily per square mile	1,810	1,930	750	1,280	1,015	768	603	487	448	347	291	400	850
Horsepower on 1 foot fall per square mile	0.318	0.340	0.131	0.225	0.179	0.135	0.106	0.086	0.079	0.061	0.051	0.070	0.149
DRIEST PERIOD.													
Inches of rainfall	4.05	3.66	4.76	3.83	0.61	2.71	3.87	0.96	1.18	0.94	3.04	2.02	31.63
Inches flowing off	3.32	3.09	4.09	3.07	1.03	.71	.69	.43	.26	.22	.23	.29	17.43
Flow in 1,000 gallons daily per square mile	1,860	1,730	2,450	1,720	595	398	400	241	145	127	129	168	828
Horsepower on 1 foot fall per square mile	0.327	0.305	0.430	0.303	0.105	0.070	0.070	0.042	0.026	0.022	0.023	0.030	0.146
DRIEST PERIOD FOR TWO YEARS.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	0.99	46.24
Inches flowing off	.40	1.94	3.58	2.83	1.54	2.13	.90	.59	.40	6.90	1.23	.80	23.24

[a] Geol. Surv. New Jersey, vol. 3, p. 240.

SOUTHWEST TRIBUTARIES TO DELAWARE RIVER.

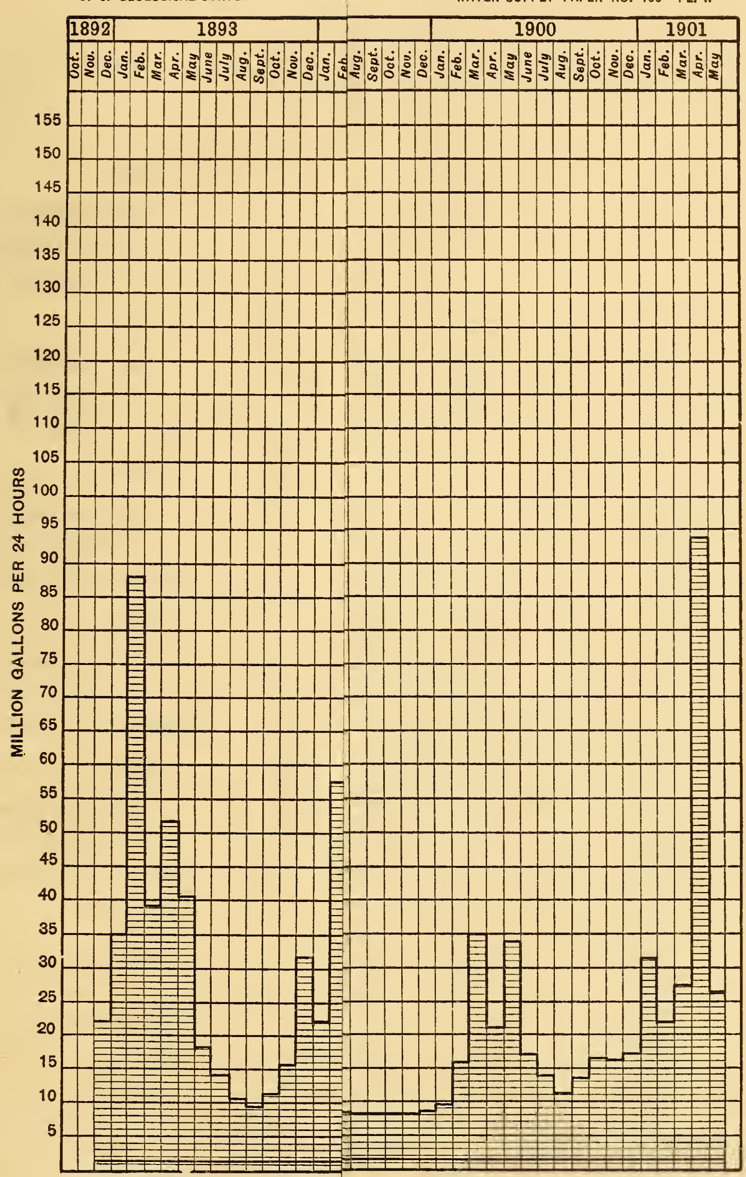
The divide between the Schuylkill and the Delaware on the southwest of the former stream lies entirely within the Paleozōic area and is approximately defined by the Philadelphia division of the Pennsylvania Railroad. The Delaware watershed west of the Schuylkill is drained by Cobbs-Darby, Crum, Ridley, and Chester creeks. (Pl. I.) These are simple streams flowing in general southeast, in the direction of the original slope of the plateau, transverse to the strike of the underlying rocks and with the prevailing dip. They have roughly parallel courses, and drainage basins of like geologic character and of approximately the same area. With a fall of 480 feet in 16 to 20 miles, they have cut rocky channels 200 feet below the level of the plateau. They flow through a fertile and cultivated country which still bears considerable woodland.

The annual rainfall computed for the three periods of the water year is given in the table on pages 25–26. The rainfall is uniform on the drainage basins of the four creeks and the flow of the streams does not differ materially. For Crum and Ridley creeks detailed observations and estimates have been made and have been furnished by Mr. Ledoux. The table groups these data in a new form. The data for Cobbs-Darby and Chester creeks can not be materially different.

Crum Creek has a drainage area of 29.47 square miles, of which approximately 40 per cent is wooded. Its minimum average monthly flow from 1892 to 1901 was 5,220,000 gallons in 24 hours, in September, 1895, and its maximum flow 138,000,000 gallons in 24 hours, in May, 1894.

Ridley Creek has a drainage area of 33.6 square miles. Its minimum computed flow between 1892 and 1901 was 5,940,000 gallons in 24 hours, in September, 1895. Its maximum observed flow was 157,500,000 gallons in 24 hours, in May, 1894. Its minimum flow occurs in August, September, and October, at the close of the growing period and the opening of the replenishing period. At this time stream flow has not begun to show the effects of the season of replenishing, and ground water, at the close of a period of maximum vegetable growth and maximum evaporation, is at its lowest level. The maximum flow occurs in March, April, or May, at the close of the storage period, when evaporation and plant absorption are at a minimum and ground and artificial storage at a maximum. Pl. II shows graphically this periodic fluctuation of stream flow. The same statements may be made for Crum Creek.

In the table on pages 25–26 are given the discharges for Crum and Ridley creeks, calculated for the three periods into which the water year has been divided by Mr. George W. Rafter. This grouping clearly shows that the greatest stream flow occurs in the storage period, December to May; the least in the growing period, June to August; and a somewhat variable mean in the replenishing period, September to November.


1892
1893
1900
1901
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
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Jan.
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May
MILLION GALLONS PER 24 HOURS
155
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
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40
35
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25
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10
5

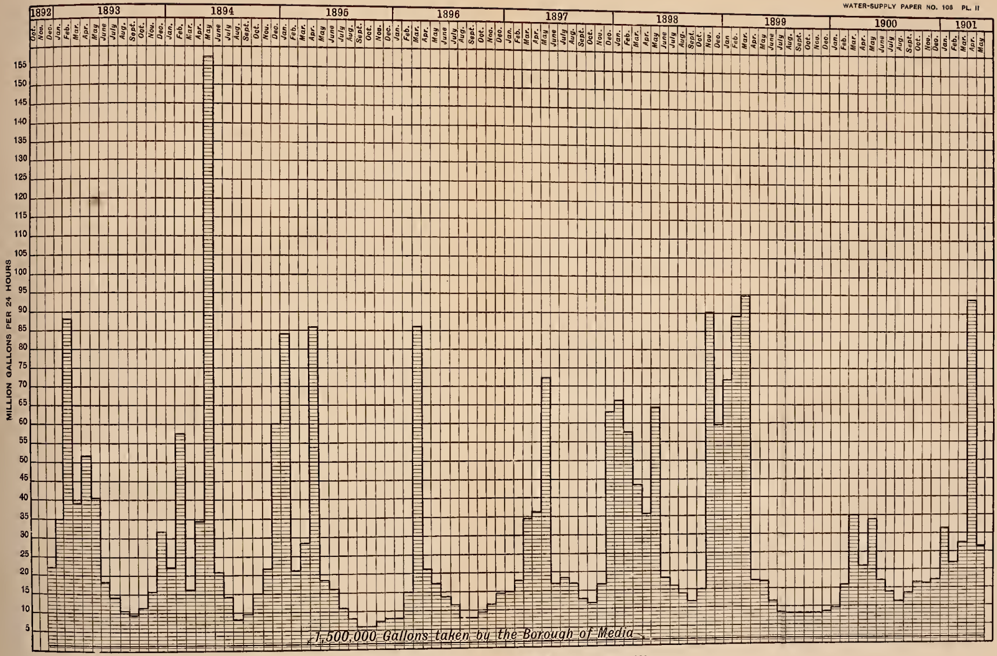

DIAGRAM OF STREAM FLOW OF RIDLEY CREEK, 1892–1901.

(Original drawing for this plate prepared by J. W. Ledoux.)

Rainfall, evaporation, and run-off of Delaware watershed west of Schuylkill River, and flow of Crum and Ridley creeks.

Months, grouped in periods.	Southwest watershed of Delaware.			Crum Creek (computed flow 29.9 square miles, in million gallons).	Ridley Creek (computed flow 33.6 square miles, in million gallons).
	Rainfall.	Evaporation.	Run-off, in inches.		
1892–93.					
December–May	22.16	7.73	14.43	243.05	276.52
June–August	10.00	11.79	2.26	38.01	43.34
September–November	10.48	5.01	1.92	32.31	36.81
1893–94.					
December–May	26.14	8.95	16.69	280.75	320.03
June–August	8.12	11.21	2.25	37.87	43.14
September–November	13.63	5.73	2.42	40.71	46.39
1894–95.					
December–May	21.97	7.33	15.54	261.66	298.07
June–August	6.03	10.63	1.83	30.79	35.13
September–November	5.30	4.20	1.01	17.00	19.36
1895–96.					
December–May	20.70	7.11	18.11	136.50	155.51
June–August	9.87	11.76	1.74	29.28	33.37
September–November	11.04	5.27	1.50	25.24	28.76
1896–97.					
December–May	19.21	7.51	9.90	166.63	189.85
June–August	14.92	13.55	2.72	45.76	52.18
September–November	8.96	4.67	2.11	35.50	40.48
1897–98.					
December–May	25.30	8.18	17.19	288.60	329.70
June–August	12.71	12.63	2.48	41.72	47.56
September–November	13.39	5.22	6.08	102.32	116.58
1898–99.					
December–May	24.51	7.51	18.21	291.88	348.92
June–August	8.10	11.40	1.44	31.97	27.61
September–November	7.42	4.74	1.26	21.21	24.15
1899–1900.					
December–May	19.29	7.43	6.42	107.98	123.11
June–August	10.70	12.05	2.19	36.85	42.01
September–November	10.07	5.31	2.40	40.36	46.03

Rainfall, evaporation, and run-off of Delaware watershed, etc.—Continued.

Months, grouped in periods.	Southwest watershed of Delaware.			Crum Creek (computed flow 29.9 square miles, in million gallons).	Ridley Creek (computed flow 33.6 square miles, in million gallons).
	Rainfall.	Evaporation.	Run-off, in inches.		
1900–01.					
December–May	20.45	7.32	11.30	190.37	216.60
June–August	15.45	13.39	2.53	42.59	48.56
September–November	6.40	4.44	2.65	44.62	50.86
1901–02.					
December–May	23.82	7.45	13.18	223.06	253.34
June–August	14.19	13.04	3.70	62.31	71.04
September–November	13.48	6.77	6.96	117.28	133.75
Average:					
December–May	22.36	7.65	13.10	219.05	251.17
June–August	11.01	12.15	2.31	39.72	44.39
September–November	10.02	5.14	2.831	47.66	54.32

In the ten years over which the observations extended there were five years (1893, 1895, 1896, 1897, 1899) when the stream flow during the replenishing period was less than during the growing period. In these years the rainfall was low in the autumn and the evaporation was high. For the ten years the average stream flow during the replenishing period is greater than the average flow during the growing period, although the average rainfall is less. Plant absorption and increased evaporation during the growing period explain the difference in the volume of flow. In the three periods of the water year the average monthly rainfall, which may be computed from the preceding table, does not vary greatly. There is a slightly greater average monthly rainfall in the storage period (0.06 of an inch) than in the growing period, and a greater average monthly rainfall in that period than in the replenishing period (0.33).

From Ridley Creek 1,500,000 gallons are taken by the water department of the borough of Media every twenty-four hours. From Crum Creek 2,000,000 gallons are taken by the Springfield Water Company and distributed as described on page 65.

Mean season rainfall in Delaware watershed west of Schuylkill River.

[1 inch per month of rainfall=571.300 gallons per twenty-four hours.]

1892–93.		1898–99.	
December-May	3.695	December-May	4.085
June-August	3.333	June-August	2.700
September-November	3.493	September-November	2.473
1893–94.		1899–1900.	
December-May	4.356	December-May	3.215
June-August	2.706	June-August	3.566
September-November	4.543	September-November	3.356
1894–95.		1900–01.	
December-May	3.661	December-May	3.408
June-August	2.010	June-August	5.150
September-November	1.766	September-November	2.133
1895–96.		1901–02.	
December-May	3.450	December-May	3.970
June-August	3.290	June-August	4.730
September-November	3.680	September-November	4.493
1896–97.		Average:	
December-May	3.201	December-May	3.73
June-August	4.973	June-August	3.67
September-November	2.986	September-November	3.34
1897–98.			
December-May	4.216		
June-August	4.236		
September-November	4.463		

NORTHEAST TRIBUTARIES TO DELAWARE RIVER.

Northeast of the Schuylkill River, Germantown and Chestnut Hill locate the divide between the Schuylkill and the Delaware. The Delaware watershed is drained by Tacony, Pennypack, and Little Neshaminy creeks, which rise in the Triassic area and flow across the Paleozoic and pre-Paleozic crystallines. Like the streams discussed above, they flow transversely to the strike of the rocks, in the direction of the dominant dip. Their valleys do not exceed 100 feet in depth. Neshaminy Creek is outside of the Philadelphia district, but the observations of its rainfall and stream flow made by the Philadelphia bureau of water supply since 1882 will be introduced in this paper,[a] as its basin is similar in character to that of the neigh-

[a] Codman, John E., Observations on rainfall and stream flow in eastern Pennsylvania: Proc. Eng. Club of Philadelphia, vol. 14, No. 2, pp. 175–178.

boring and parallel creek, Pennypack, on which no observations have been made.

The Neshaminy rises in the Triassic area and flows across the Paleozoic and pre-Paleozoic crystalline rocks of the Philadelphia district into the Delaware. Its watershed comprises an area of a little more than 139.3 square miles and lies mainly east of the Philadelphia district. The Neshaminy has a fall of about 600 feet in the 27 miles from source to mouth. This grade has given the stream good corrasive power, and it has cut a moderately deep valley into the plateau. It and the adjacent streams are subject to spring and winter freshets. At these periods volume and velocity may be increased a hundredfold. The drainage basins of Neshaminy and Pennypack creeks constitute a dissected plateau of moderate elevation and contain excellent farming land, which is under a high degree of cultivation. Forests have been sacrificed to agricultural interests, and are now found only on steep hillsides or on the bottom land bordering the creeks. The proportions of woodland and cultivated land in the Neshaminy basin are as follows: Woodland, about 6 per cent; cultivated land, about 92 per cent; roads, 2 per cent, and flats, one-half of 1 per cent.

Under such surface conditions the spring rainfall is not retained by ground storage. The run-off is proportionally large; great quantities of surface soil are carried off; the streams become torrential and transport a heavy load of fine sediment. The opaque, rich reddish yellow color of the water after heavy rains, due to the large amount of finely divided material in suspension, is a characteristic feature of streams in this area.

The conditions which diminish the ground storage increase the evaporation during the summer months, hence there is marked seasonal fluctuation in the stream flow. In summer the soil is parched and cracked by evaporation; the level of ground water falls lower than the surface springs and upper courses of the tributaries; the springs dry up and the streams are reduced.

As in the case of Crum and Ridley creeks, the stream flow is usually greatest in January, February, and March, and least in August, September, and October.

The average daily flow of the Neshaminy is 157,600,000 gallons, or 1,130,000 gallons per square mile. The maximum flow has been 3,700,000,000 gallons per day, and the minimum flow 2,800,000 gallons per day. It has been asserted that a draft of 1,000,000 gallons per day per square mile of watershed could be made upon Pennsylvania streams.

The average rainfall from 1884 to 1897 at 22 stations where observations were made by the Philadelphia bureau of water was about 48.5 inches. Of this average rainfall nearly 50 per cent, or 24.1 inches, flowed off in the streams.

The diagram, Pl. III, shows the storage and run-off of the Neshaming, and in the next table are given the mean monthly rainfall, mean

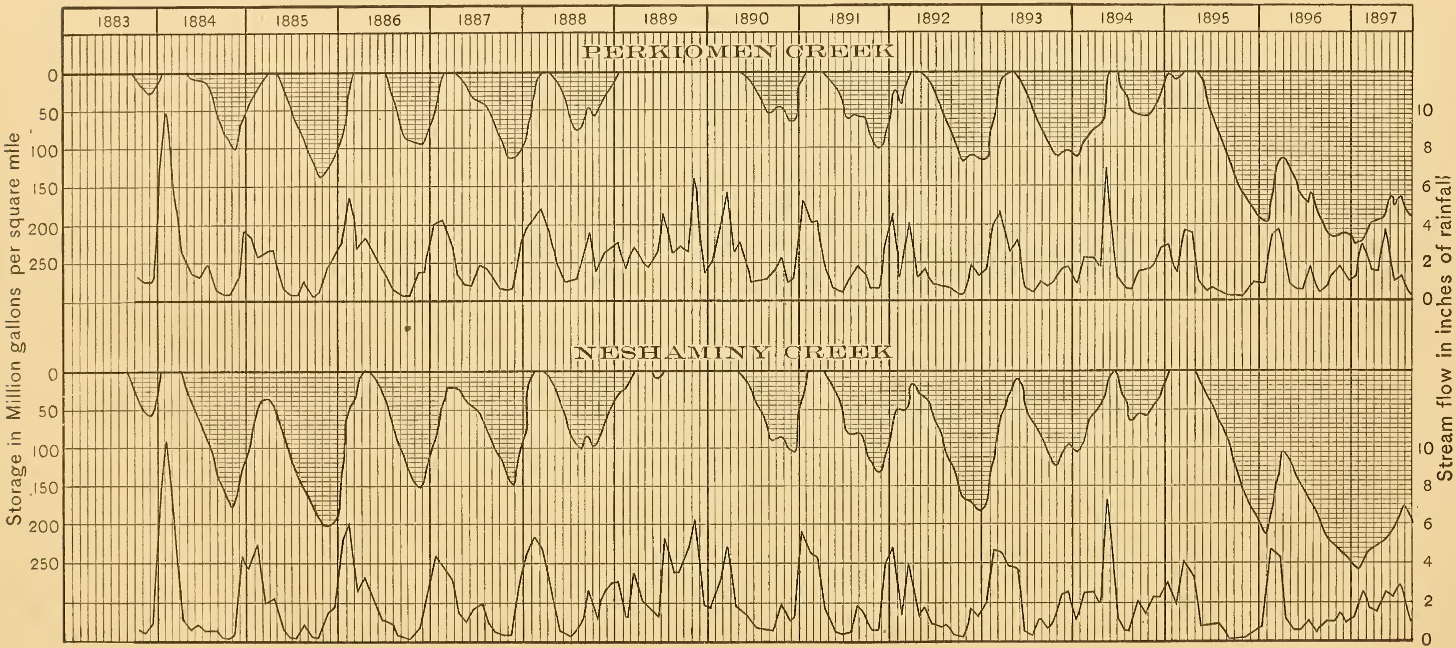

DIAGRAM SHOWING STORAGE AND RUN-OFF OF PERKIOMEN AND NESHAMINY CREEKS.

(From Proc. Eng. Club of Phila., Vol. XIV, No. 2, 1897.)

monthly run-off, and mean annual evaporation on the Neshaminy watershed, as determined from observations made by Mr. Codman, chief engineer of the Philadelphia bureau of water.

These figures very clearly show that in the Neshaminy watershed during the storage period, December to May, the stream flow most nearly equals rainfall. This is undoubtedly due to rain falling upon frozen ground, to a minimum amount of evaporation, and to the absence of plant absorption. Under these conditions the rain water finds its way immediately to the streams.

These figures also show that the stream flow is lowest in proportion to rainfall during the growing period, June to August, when the ground is soft and plant absorption and evaporation are at a maximum. In this climate these conditions are more or less continued into September and October, and only in November does the Neshaminy begin to regain its volume.

Rainfall and run-off, Neshaminy Creek, Pennsylvania, from 1883 to 1903.[a]

[Area of watershed, 139.3 square miles.]

Year.	October.		November.		December.		January.		February.	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	3.80	0.48	1.43	0.35	3.06	0.85	5.58	6.77	6.27	10.45
1884–85	3.05	.06	3.69	.33	5.70	4.56	3.76	3.50	4.93	5.18
1885–86	5.56	.17	4.50	1.53	2.88	1.73	5.11	5.21	6.18	6.55
1886–87	2.77	.06	3.92	.55	3.30	2.34	4.63	4.22	5.05	3.94
1887–88	1.90	.36	1.63	.26	6.13	2.88	4.47	4.60	3.98	5.49
1888–89	3.76	1.05	3.49	2.34	3.72	3.16	3.61	2.92	1.90	.90
1889–90	5.09	2.55	8.53	6.31	1.88	1.88	2.88	1.60	4.28	3.00
1890–91	6.18	2.16	1.06	.78	2.86	1.37	6.28	5.78	4.61	4.47
1891–92	3.66	.55	1.88	.56	4.19	3.02	5.09	5.14	1.07	.97
1892–93	.40	.04	7.14	1.79	1.69	1.15	3.13	2.00	5.68	4.89
1893–94	3.30	.59	4.41	2.58	2.78	2.61	1.71	.79	4.05	2.68
1894–95	5.25	1.48	3.02	2.37	4.14	2.31	4.68	3.46	1.12	1.77
1895–96	3.26	.08	2.21	.11	1.85	.40	1.31	.59	7.79	4.73
1896–97	2.64	.93	4.13	1.52	.85	.76	2.04	1.29	3.20	2.53
1897–98	2.50	.16	5.23	1.17	4.84	3.26	3.96	3.10	3.55	3.51
1898–99	4.86	.22	6.05	3.01	3.59	3.46	3.90	3.41	6.20	4.12
1899–1900	1.75	.28	2.19	1.04	2.52	.74	3.52	2.71	4.44	5.12
1900–1901	2.54	.15	2.34	.40	2.47	.75	2.41	1.15	.96	.34
1901–2	1.25	.33	2.58	.64	7.47	4.54	3.24	2.35	6.56	6.56
1902–3	6.40	4.55	1.66	.76	6.99	5.55	------	------	------	------
Mean	3.49	.81	3.55	1.41	3.64	2.36	3.75	3.19	4.31	4.06

[a] Compiled from reports of Philadelphia bureau of water, 1884-1903, by R. S. Lea, with additional data for 1903.

Rainfall and run-off, Neshaminy Creek, Pennsylvania, etc.—Continued.

Year.	March.		April.		May.		June.		July.	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1883-84	5.20	5.55	2.42	1.64	3.24	0.35	5.24	0.82	4.89	0.52
1884-85	1.04	1.84	2.26	2.21	2.44	.56	1.68	.08	2.19	.04
1885-86	3.72	2.30	2.93	3.57	5.79	2.09	5.67	.91	5.40	.81
1886-87	3.58	3.25	3.17	1.46	2.15	.71	7.27	1.67	8.15	1.96
1887-88	5.15	4.89	3.88	2.79	2.87	.52	2.34	.22	3.71	.15
1888-89	3.37	2.90	4.83	2.07	4.89	1.49	5.25	1.16	12.42	5.47
1889-90	5.36	5.09	2.46	1.77	5.20	1.51	4.51	.99	4.47	.63
1890-91	4.91	4.32	1.90	1.48	2.92	.32	3.46	.24	5.71	.34
1891-92	4.13	3.56	2.24	1.03	5.83	1.29	3.38	.58	4.83	.53
1892-93	2.66	4.66	4.97	2.88	4.03	2.94	3.20	.45	1.60	.13
1893-94	1.61	2.67	3.04	2.00	13.49	7.41	2.55	1.05	3.72	.43
1894-95	3.17	4.26	5.32	3.34	2.54	.70	4.30	.52	3.74	.88
1895-96	5.09	4.37	1.63	1.07	2.85	.38	4.70	.41	5.12	1.04
1896-97	2.21	1.73	3.36	1.53	7.62	2.76	5.21	2.46	9.10	2.96
1897-98	3.04	1.51	3.87	1.69	6.43	3.80	.91	.44	3.46	.19
1898-99	6.58	7.41	1.39	1.07	1.43	.44	1.62	.13	3.49	.19
1899-1900	2.98	3.13	2.47	1.22	7.05	2.31	6.66	.83	4.13	.38
1900-1901	5.08	3.48	5.07	3.48	5.59	2.10	2.52	.89	6.95	1.48
1901-2	4.45	5.30	3.40	2.14	1.79	.41	5.51	.50	3.80	.61
1902-3	------	------	------	------	------	------	------	------	------	------
Mean	3.86	3.80	3.19	2.02	4.64	1.69	4.00	.76	5.10	.99

Rainfall and run-off, Neshaminy Creek, Pennsylvania, etc.—Continued.

Year.	August.		September.		Total.		Evaporation.
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Yield.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	3.58	0.51	0.31	0.06	45.02	28.35	16.67
1884–85	6.38	.96	1.16	.03	38.28	19.35	18.93
1885–86	1.60	.15	.91	.05	50.25	25.07	25.18
1886–87	3.84	.81	4.06	.41	51.89	21.38	30.51
1887–88	5.78	.64	6.93	2.63	48.78	25.43	23.35
1888–89	4.75	3.37	8.56	3.51	60.55	30.34	30.21
1889–90	5.30	.53	2.99	.39	52.95	26.25	26.70
1890–91	6.73	1.95	2.54	1.27	49.16	24.48	24.68
1891–92	3.37	.20	2.59	.11	42.26	17.54	24.72
1892–93	7.41	1.12	3.36	.57	45.27	22.61	22.66
1893–94	2.68	.34	8.18	2.27	51.52	25.42	26.10
1894–95	3.37	.67	.74	.05	41.39	21.76	19.63
1895–96	.98	.20	5.88	.96	42.67	14.34	28.33
1896–97	3.39	1.08	1.33	.22	45.08	19.77	25.31
1897–98	7.97	1.06	1.88	.10	47.64	19.99	27.65
1898–99	4.30	1.44	6.97	.64	50.38	25.54	24.84
1899–1900	2.68	.19	2.65	.09	43.04	18.04	25.00
1900–1901	7.43	2.74	4.05	1.57	47.41	18.53	28.88
1901–2	4.30	.90	5.38	1.12	49.73	25.40	24.33
1902–3	......	......	......	......	50.36	29.82	....
Mean	4.52	.99	3.71	.84	47.68	22.97	24.93

SCHUYLKILL RIVER.

Somewhat more than one-fourth of the total length of the Schuylkill River, or 30 miles, lies in the Philadelphia district. Its drainage basin has an area of 1,915 square miles. The river has its headwaters in the anthracite coal regions of Schuylkill County, flows across the Triassic sediments and the Paleozoic and pre-Paleozic crystallines of the Piedmont Plateau, and empties into the Delaware at Philadelphia. From source to mouth the Schuylkill has a fall of about 800 feet, or an average grade of 8 feet to the mile. Most of this fall is above Reading. From Reading to Norristown, a distance of 41 miles, the fall is 141 feet, or 3½ feet to a mile; from Norristown to the Delaware, a distance of 18 miles, it is 60 feet, or 3⅓ feet to a mile.

Above Reading the Schuylkill is highly charged with sulphuric acid and iron sulphate. This acid is neutralized near Reading by the entrance of two tributaries from the limestone belt bearing calcium carbonate in solution. From Reading to Norristown the towns on the Schuylkill obtain their water supply from the river. From Norristown to Philadelphia all sewage and industrial refuse of the towns along the stream drain into it. Until the present year this water has been pumped at five stations and distributed unfiltered to the city of Philadelphia. Over 90 per cent of the water consumed in Philadelphia comes from the Schuylkill, the remainder being furnished by the Delaware River.

In this connection it is of interest to note that the average number of bacteria per cubic centimeter of Schuylkill River water for 1902 was 14,160. The maximum for the same year was 86,000 and the minimum 630 per cubic centimeter.

Precipitation and stream flow on the Schuylkill, as observed by Mr. Codman, are shown in the table on page 33.

Mr. Codman states that with no additional storage the Schuylkill will furnish a supply of at least 225,000,000 gallons per day. With an artificial storage of probably not more than 100,000,000 gallons per square mile of the watershed of 1,800 square miles above Norristown, the Schuylkill could be depended upon for a supply of 1,000,000,000 gallons per day. The natural facilities afforded for storage dams are such that the above volume of water could be safely and cheaply stored.

Comparison of rainfall flowing off in the Perkiomen and Neshaminy creeks and Schuylkill River.

Year.	Perkiomen.	Neshaminy.	Schuylkill.
	Inches.	*Inches.*	*Inches.*
1898	21.50	22.22	24.39
1899	24.66	21.06	22.29
1900	15.21	17.27	18.23
1901	17.55	22.88	17.80
1902	29.01	30.74	29.02

Rainfall and run-off in basin of Schuylkill River.[a]

[Drainage area, 1,915 square miles.]

Month.	Rain-fall.	Run-off.		Monthly yield of stream.	Average daily yield of stream.		Average yield per second per square mile.
1901.	*Inches.*	*Inches.*	*Per ct.*	*Cubic feet.*	*Cubic feet.*	*Gallons.*	*Cubic feet.*
October	1.670	0.914	55	4,065,530,000	131,134,000	981,030,000	0.7926
November	2.280	.585	25	2,596,150,000	86,538,000	647,350,000	.5230
December	7.970	3.315	43	14,753,200,000	475,910,000	3,560,030,000	2.8763
1902.							
January	3.540	3.228	91	14,360,500,000	463,242,000	3,465,290,000	2.8000
February	6.040	4.107	68	18,278,000,000	652,785,000	4,883,170,000	3.9453
March	4.420	5.439	123	24,204,200,000	780,779,000	5,840,530,000	4.7190
April	3.690	2.623	71	11,673,500,000	389,016,000	2,910,790,000	2.3519
May	1.510	.990	65	4,400,760,000	142,180,000	1,063,600,000	.8590
June	6.320	.548	8	2,384,770,000	79,492,000	594,430,000	.4810
July	4.280	.807	18	3,589,200,000	115,780,000	866,097,000	.7000
August	3.520	.730	21	3,248,420,000	104,784,000	783,842,000	.6330
September	6.500	.963	15	4,283,540,000	142,763,000	1,068,000,000	.8630
Total	51.740	24.233	46	107,837,770,000	295,446,000	2,210,090,000	1.7822
October	5.982	2.748	46	12,229,800,000	394,510,000	2,951,140,000	2.3844
November	1.730	1.290	74	5,741,780,000	191,393,000	1,431,620,000	1.1567
December	7.110	5.582	78	24,842,000,000	801,343,000	5,994,500,000	4.8432
Total		29.016					

[a] Report of the bureau of water, Philadelphia, 1903.

Monthly precipitation, in inches, on sundry watersheds.[a]

	Philadelphia district.					Schuylkill basin.				
	United States Weather Bureau.	Water bureau auto.	Water bureau ground gage.	Pennsylvania Hospital.	Shawmut.	Lebanon.	Reading.	Pottsville.	Browers.	Hamburg.
Elevation above sea level (feet)	207	66	49	25	368	480	207	150	86	365
1902.										
January	2.77	2.40	2.51	2.55	2.09	3.62	3.45	4.41	3.55	4.09
February	5.49	5.24	5.12	4.02	5.09	5.67	6.72	5.64	......	6.44
March	3.97	2.20	2.25	6.10	3.59	4.79	3.00	5.49	3.80	4.38
April	3.29	3.14	3.27	3.29	3.06	3.38	3.96	4.36	3.12	4.59
May	2.01	1.60	1.67	3.51	1.73	.43	1.09	.87	2.03	.....
June	6.08	6.07	6.29	5.26	5.10	6.18	5.29	7.12	7.05	.....
July	3.51	4.20	4.34	5.50	4.52	4.21	3.52	6.43	3.83	.....
August	2.34	2.94	3.05	2.59	2.90	5.49	4.31	5.01	3.04	.....
September	4.97	5.26	5.48	4.61	4.31	4.43	6.87	6.34	5.91	6.06
October	6.66	5.65	5.51	8.02	6.29	5.93	4.50	6.04	6.39	3.98
November	2.04	1.53	1.54	2.47	1.75	1.45	1.76	1.61	2.11	.51
December	6.63	6.68	6.67	7.67	6.39	7.46	7.10	7.80	7.20	6.64
Total	49.76	47.11	47.70	55.59	46.82	53.04	51.57	61.12	54.12	.....
Per cent	100	95	96	112	94	107	104	123	109	.....
20 years yearly average:										
Inches	40.15	41.08	43.71	44.97	44.20	45.32	42.82	56.36	44.57	.....
Per cent	100	102	108	112	111	113	107	141	108	.....
Average increase, 1902:										
Inches	9.61	6.03	6.99	10.62	2.62	7.72	8.75	4.76	9.55	.....
Per cent	24	15	17	26	65	19	22	85	24	.....

[a] Report of the bureau of water, Philadelphia, 1903.

Monthly precipitation, in inches, on sundry watersheds—Continued.

	Perkiomen basin.		Delaware basin.			Neshaminy basin.		
	Seisholtzville.	Springmount.	Easton.	Moorestown.	Westchester.	Lansdale.	Forks of Neshaminy.	Doylestown.
Elevation above sea level (feet)	870	300	340	65	455	350	143	405
1902.								
January	4.39	2.80	2.49	....	4.06	3.19	2.53	4.00
February	6.49	5.72	5.80	....	7.18	6.92	5.32	7.43
March	4.55	3.41	3.37	....	4.65	3.74	3.45	6.16
April	4.32	2.61	3.35	....	4.63	3.53	3.39	3.28
May	2.08	2.42	2.22	....	1.60	1.52	2.02	1.83
June	6.54	4.74	6.50	....	6.75	3.50	6.89	6.13
July	3.89	2.77	4.52	....	3.61	2.68	4.70	4.03
August	6.17	1.94	3.65	....	4.12	3.15	4.61	5.14
September	7.24	7.83	8.31	....	7.00	4.08	5.74	6.33
October	6.05	6.26	5.35	....	7.92	5.39	6.05	7.77
November	1.74	2.13	1.26	....	2.60	1.63	1.75	1.59
December	8.51	6.35	7.22	....	7.95	6.45	6.59	7.94
Total	61.97	48.98	54.04	....	62.07	45.78	53.04	61.63
Per cent	125	99	109	....	125	92	107	124
20 years yearly average:								
Inches	50.25	45.69	46.07	....	51.61	45.81	46.47	48.47
Percentage	122	114	115	....	128	114	116	118
Average increase, 1902:								
Inches	11.72	3.29	7.97	....	10.46	[b].03	6.57	13.16
Per cent	29	82	20	......	26	[b].00	16	32

[b] Decrease.

SCHUYLKILL TRIBUTARIES.

The chief tributaries of the Schuylkill are the Perkiomen, the Pickering, and the Wissahickon. The less important ones are Valley, Trout, Gulf, and Mill creeks. Valley and Gulf creeks possess peculiar courses, which are evidently due to stream capture. They turn abruptly away from direct courses to the Schuylkill and cut deep ravines through ridges of hard rock. These minor tributaries drain the southwest side of the Schuylkill basin, and their drainage area is being extended into the area now drained by the southwestern tributaries of the Delaware.

The Perkiomen, which flows through the Philadelphia district in the last 10 miles of its course, has its source in the Paleozoic crystallines to the northwest of the Triassic formations. Its watershed is almost wholly in the Triassic shale belt, and comprises an area of 447.59 square miles, 152 square miles of which are above the gaging station at the entrance of the Northeast Branch. The Perkiomen falls from its source to the gaging station about 800 feet in 24 miles, and from the gaging station to its mouth 40 feet in 11 miles. The drainage basin of the Perkiomen is similar in character to that of the Neshaminy, which is contiguous on the northeast, and which has already been discussed. The proportions of woodland, cultivated land, etc., for the Perkiomen are as follows:[a] Woodland, 20 per cent; cultivated land, 77.5 per cent; flats, 0.5 per cent; roads, 2 per cent.

Observations of the rainfall and run-off of the Perkiomen have been made by Mr. Codman for twenty years, and the results are shown in the table on pages 37–39 and also on Pl. III (p. 28). The facts that were brought out in the case of the Neshaminy are shown with equal clearness for the Perkiomen.

While the months of January, February, and March are usually months of maximum flow, and August, September, and October months of minimum flow, these conditions are sometimes reversed. This is shown by the record of the Perkiomen, on which the maximum flow for one day for the year 1888—22,500,000 gallons per square mile of watershed—occurred in September and has been exceeded but a few times since.

The maximum observed flow up to the present time (1904) for one day was 27,300,000 gallons per square mile of watershed, on February 28, 1902; while the minimum observed flow for one day was only 21,700 gallons per square mile, in September, 1885.

The average daily flow of the Perkiomen from 1884 to 1897 was 177,900,000 gallons, or 1,160,000 gallons per square mile of the watershed above the gaging station. The maximum flow was 4,149,600,000 gallons per day, more than eighteen days' pumpage of all the Philadelphia water bureau plant, and the minimum flow was 3,800,000 gallons per day, or about twenty-five minutes' pumpage.

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[a] Codman, John E., op. cit., p. 181.

Rainfall and run-off, Perkiomen Creek, Pennsylvania, from 1883 to 1903.[a]

[Area of watershed, 152 square miles.]

Year.	October.		November.		December.		January.		February.	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883-84	5.27	1.42	1.93	0.91	4.00	1.04	5.14	5.40	5.04	9.73
1884-85	3.69	.37	3.26	.91	6.08	3.77	3.76	3.27	4.41	2.16
1885-86	4.74	.43	3.88	1.79	3.18	2.45	4.21	3.03	5.08	5.64
1886-87	2.35	.26	5.28	1.53	3.76	1.43	4.55	4.00	5.64	4.23
1887-88	1.45	.43	1.61	.40	6.65	2.13	5.01	3.66	4.08	4.41
1888-89	3.41	1.26	3.42	2.46	4.37	2.88	3.86	3.27	1.99	1.47
1889-90	4.78	2.34	8.66	6.67	1.70	1.27	2.81	2.05	4.37	3.58
1890-91	5.48	2.35	1.12	.87	2.71	1.14	6.30	5.29	3.84	4.18
1891-92	3.53	.56	1.99	.60	4.73	2.89	5.56	4.79	1.25	1.17
1892-93	.48	.20	6.64	2.13	1.88	1.22	2.38	1.45	5.53	4.04
1893-94	2.82	.89	4.22	1.84	2.75	1.90	1.78	.70	4.22	2.42
1894-95	6.24	1.66	2.80	1.85	4.81	2.83	4.30	3.06	1.58	1.25
1895-96	3.46	.23	1.86	.34	3.13	.91	.91	.59	5.97	3.50
1896-97	4.72	1.48	4.72	2.06	.65	.81	2.05	1.18	2.90	2.93
1897-98	2.06	.22	6.38	1.75	4.37	2.76	4.04	2.56	3.18	3.33
1898-99	5.12	.59	6.60	3.08	3.64	3.25	3.48	3.57	4.44	4.51
1899-1900	1.29	.56	2.61	1.02	1.72	.94	2.62	2.24	5.04	5.07
1900-1901	2.16	.29	2.25	.37	2.53	.64	2.38	1.05	.69	.30
1901-2	1.86	.61	2.31	.53	7.17	4.22	3.60	2.68	5.11	5.39
1902-3	6.16	2.78	1.94	.90	7.43	6.45	......	......	......	......
Mean	3.56	.95	3.68	1.60	3.87	2.25	3.62	2.83	3.91	3.65

[a] Compiled from reports of Philadelphia bureau of water, 1884-1903, by R. S. Lea, with additional data for 1903.

Rainfall and run-off, Perkiomen Creek, Pennsylvania, etc.—Continued.

Year.	March.		April.		May.		June.		July.	
	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	5.04	5.29	2.63	2.37	3.40	1.36	4.65	1.26	7.44	2.16
1884–85	1.32	2.52	2.41	2.75	2.49	.82	1.48	.28	2.18	.17
1885–86	3.96	2.56	3.00	3.42	6.60	2.64	5.26	1.89	5.06	1.11
1886–87	2.99	3.03	2.84	1.25	1.85	.72	5.87	.76	8.63	2.07
1887–88	5.15	5.10	3.43	3.45	3.16	.92	1.62	.39	2.77	.25
1888–89	3.17	3.01	5.05	2.07	4.55	1.58	7.16	2.65	12.23	4.89
1889–90	6.56	5.58	2.79	2.51	6.43	3.15	2.40	.94	5.19	1.09
1890–91	6.07	4.29	1.98	1.80	1.99	.65	3.02	.36	7.73	.85
1891–92	4.99	4.05	1.79	1.16	5.32	1.83	3.18	.89	5.19	.73
1892–93	2.90	4.93	4.11	2.30	5.36	3.27	3.75	.56	2.00	.30
1893–94	1.45	2.38	2.54	1.71	11.63	6.66	3.61	1.13	2.93	.58
1894–95	2.96	3.91	6.12	3.48	3.45	.98	3.56	.43	3.96	.61
1895–96	4.43	3.83	1.85	.97	3.70	.43	4.53	.48	9.31	2.01
1896–97	2.38	1.83	3.30	1.64	8.72	3.98	3.17	.93	7.79	1.56
1897–98	2.56	1.56	3.86	1.68	6.22	3.83	.96	.42	2.85	.33
1898–99	5.83	6.59	2.00	1.80	3.41	.76	3.90	.54	5.76	.79
1899–1900	2.88	2.49	1.96	1.31	2.98	.89	3.01	.34	4.97	.96
1900–1901	5.34	3.34	5.18	2.48	4.90	1.79	2.36	.87	5.13	.34
1901–2	3.93	5.05	3.47	2.21	2.20	.75	5.64	.53	3.33	.55
1902–3	------	------	------	------	------	------	------	------	------	------
Mean	3.89	3.75	3.17	2.12	4.64	1.95	3.64	.82	5.50	1.12

Rainfall and run-off, Perkiomen Creek, Pennsylvania, etc.—Continued.

Year.	August.		September.		Total.		Evapo. ration.
	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	3.44	0.65	0.59	0.31	48.57	31.90	16.67
1884–85	6.17	1.23	.87	.16	38.12	18.41	19.71
1885–86	1.44	.35	1.37	.23	47.78	25.54	22.24
1886–87	2.76	1.43	3.64	.62	50.16	21.33	28.83
1887–88	8.03	1.53	7.35	3.68	50.31	26.35	23.96
1888–89	3.99	2.48	7.00	2.80	60.20	30.82	29.38
1889–90	6.75	1.08	3.71	1.30	56.15	31.56	24.59
1890–91	7.57	2.04	2.63	1.53	50.44	25.35	25.09
1891–92	2.69	.76	2.21	.33	42.43	19.76	22.67
1892–93	6.45	.96	3.14	.60	44.62	21.96	22.65
1893–94	2.23	.34	6.36	1.67	46.54	22.22	24.32
1894–95	3.36	.28	.93	.18	44.07	20.52	23.55
1895–96	1.21	.34	5.18	.65	45.54	14.31	31.23
1896–97	2.73	.59	1.62	.29	44.75	19.28	25.47
1897–98	6.16	.63	2.22	.22	44.86	19.29	25.57
1898–99	4.46	1.13	7.46	2.44	56.10	29.06	27.01
1899–1900	3.74	.41	1.80	.24	34.62	16.47	18.15
1900–1901	8.70	1.39	3.27	.63	44.89	13.49	31.40
1901–2	4.06	.52	7.54	1.21	50.27	24.25	26.02
1902–3					52.84	31.96	
Mean	4.52	.96	3.63	1.01	47.66	23.19	24.66

Pickering Creek, which is shown on the western edge of the Norristown atlas sheet, is the smallest of the larger tributaries of the Schuylkill River. It has a drainage basin of 65.88 square miles. It flows for the most part through pre-Cambrian gneiss, but for the last 3 miles of its course over Triassic formations. Its minimum daily flow is estimated at 4,000,000 gallons, and its maximum daily flow at 4,000,000,000 gallons.

Wissahickon Creek drains the area between the drainage basins of the Little Neshaminy and the Perkiomen. It rises near Lansdale, in the northern portion of the Philadelphia district, and flows southerly for 20 miles, emptying into the Schuylkill River at Fairmount Park. It is one of the three chief tributaries of the Schuylkill in the Philadelphia district and is the most important of the creeks that are wholly within the district. Its watershed has an area of 64.6 square miles and is composed partly of the Triassic formations and partly of Paleozoic crystallines. The creek has a fall of 420 feet from source to mouth, or an average descent of 21 feet to a mile. From Chestnut Hill to the Schuylkill, a distance of 6 miles, there is a descent of 100 feet, or about 17 feet to the mile. In this portion of its course the stream has cut a gorge to a depth of about 200 feet below the general level of the country. Here the banks are wooded and steep, but in a portion of its upper course the stream is bordered by an open valley, which is part of a fertile and cultivated farming region. As on Neshaminy Creek, the percentage of woodland is small.

The monthly rainfall and the monthly and average daily flow of the Wissahickon from October, 1901, to April, 1902, as observed by Mr. Codman, are given in the following table.

Precipitation and stream flow on the Wissahickon watershed.[a]

[Area, 64.6 square miles.]

	Rainfall.	Rainfall flowing off.	Percentage flowing off.	Monthly yield of stream.	Average daily yield of stream.		Average yield per second per square mile.
1901.	*Inches.*	*Inches.*		*Cubic feet.*	*Cubic feet.*	*Gallons.*	*Cu. ft.*
October	1.355	0.541	40	81,112,000	2,616,500	19,573,000	0.468
November	2.705	.647	24	97,105,000	3,236,900	24,213,200	.580
December	6.765	2.430	36	364,824,000	11,768,500	88,034,000	2.1085
1902.							
January	2.640	1.798	68	269,931,000	707,430	65,136,200	1.5601
February	5.960	4.462	75	669,574,000	23,913,400	178,884,000	4.2844
March	3.665	4.629	126	694,768,000	22,411,900	167,653,000	4.0154
April	3.295	2.321	77	348,296,000	11,609,800	86,847,700	2.0801

[a] Report of bureau of water, Philadelphia, 1903.

Owing to a leak in the new dam above the automatic gage, it was necessary to drain off the lower reservoir, putting an end to stream observations after May 22, 1902. It will be noted that the storage of rainfall during December and January is somewhat greater in the Wissahickon than in the watersheds heretofore discussed.

In the following tables comparative figures of rainfall and run-off are given for a number of the watersheds of tributaries of the Delaware and Schuylkill and for a few other streams:

Run-off, in inches, of Perkiomen and Neshaminy drainage areas.

Watershed.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Perkiomen at Frederick:												
Average for 19 years	2.84	3.66	3.77	2.12	1.43	0.82	1.25	0.95	0.96	0.92	1.58	2.32
Maximum in 19 years	5.40	9.73	5.58	3.48	6.66	2.65	4.89	2.48	3.68	2.77	6.67	6.45
Minimum in 19 years	.59	1.25	2.38	.97	.46	.28	.17	.28	.16	.20	.24	.63
Neshaminy below Forks:												
Average for 19 years	3.20	4.12	3.55	2.05	1.89	.75	1.03	.99	.84	.81	1.42	2.46
Maximum in 19 years	6.77	10.41	5.55	3.57	7.41	2.46	5.47	3.37	3.51	4.55	6.31	5.55
Minimum in 19 years	1.60	.90	1.84	1.03	.35	.08	.04	.14	.03	.06	.11	.41

Comparative daily stream flow of certain streams of Philadelphia district, 1901 and 1902.[a]

Watershed.	Area of watershed.	Maximum.			Minimum.		
		Gallons per day.	Gallons per square mile.	Date.	Gallons per day.	Gallons per square mile.	Date.
Perkiomen	152	4,420,000,000	27,300,000	Feb. 28	11,631,000	76,400	Aug. 25
Neshaminy	139.3	3,930,000,000	28,250,000	Feb. 26	8,080,000	57,800	July 21
Wissahickon	64.6	1,288,200,000	20,000,000	Feb. 28	----------	----------	
Schuylkill	1,915	53,098,600,000,000	27,700,000	Mar. 1	----------	----------	

Average annual yield of sundry watersheds to October 1, 1902.[a]

Watershed.	Period covered, years.	Area.	Average rainfall.	Average fall flowing off.	Per cent flowing off.	Average annual yield.	Average daily yield.	Average yield per second per square mile of drainage area.	Average yield per second per square mile of drainage area for each inch of rainfall.
		Miles.	*Inches.*	*Inches.*		*Gallons.*	*Gallons.*	*Cu. ft.*	*Cu. ft.*
Perkiomen at Frederick	19	152	47.366	22.696	48	59,948,940,000	164,211,500	1.6716	0.0353
Neshaminy, below Forks	19	139.3	47.721	2.484	47.118	54,427,535,000	149,093,800	1.6561	.0347
Tohickon	19	102.2	48.685	27.344	56.200	48,592,436,000	133,023,000	2.0140	.0413
Wissahickon[b]	----	64.6	--------	--------	--------	----------	----------	--------	--------
Schuylkill	4	1,915	47.135	20.843	48.400	----------	1,900,801,000	1.5359	.0325
Sudbury, Mass	27	72.5	46.39	22.702	48.90	----------	78,371,000	1.6750	.0362
Croton, N. Y	19	338	45.97	22.760	49.50	135,400,000,000	371,600,000	1.680	.0365

[a] Report of the bureau of water, Philadelphia, 1903.
[b] No record after April.

COASTAL PLAIN HYDROGRAPHIC BASIN.

DRAINAGE.

The portion of the Coastal Plain included in the Philadelphia district lies wholly within the watershed of the Delaware River and hence slopes toward that stream. Its greatest altitude, in the extreme southeast corner of the Philadelphia quadrangle, is 180 feet above sea level. Its streams are all subsequent, and tributary to the Delaware. Pensauken, Cooper, Big Timber, Woodbury, Mantua, Raccoon, and Oldmans creeks are simple streams, which have their sources in the upper Cretaceous marls or on the boundary of the Miocene sands, and flow northwest across the marls, clay marls, and plastic clays of the Cretaceous into the Delaware. As the streams flow through unconsolidated materials and have an average fall of only 8 feet to a mile, their valleys are shallow and interrupted by mill ponds in the upper courses, and flat and marshy with meandering channels in the lower courses. The creeks are from 10 to 16 miles long and are tidal for about half their total length. Owing to this fact they have, as will be seen by the tables given below, little importance for water-power purposes. According to the observations made by the New Jersey geological survey these streams are in a district which shows little difference between the average rainfall and the average evaporation. This means that the average run-off of these streams is smaller than that of streams of the same class elsewhere in the State.

Pensauken Creek empties into the Delaware River at Morris. It drains 35.4 square miles. The geological survey of New Jersey reports that—

Its watershed is populous and highly cultivated, and the stream is tidal for about half its length, consequently it has little importance. Moorestown is supplied from its headwaters, but the quality of its water is said to be unsatisfactory. The average flow at the mouth of the stream is 39,900,000 gallons daily, and the least monthly flow 5,900,000 gallons daily.[a]

Cooper Creek empties into the Delaware at Camden. It is tidal to the forks at Haddonfield, and the lower portion of its watershed is populous and highly cultivated. The average flow is estimated by the New Jersey survey at 40,000,000 gallons daily and the flow for the driest month at 6,800,000 gallons daily.

Above the pond at Haddonfield the minimum flow is 3,050,000 gallons daily. With storage amounting to 3.28 inches it will furnish 8,600,000 gallons daily.

The only part of Cooper Creek which is worthy of serious consideration as a water supply is North Branch. Its watershed is 11.7 square miles and the flow for the driest month 1,960,000 gallons daily, or with 3.28 inches storage it will yield 5,660,000 gallons daily. The opportunities for storage are very good, but like all streams with marl outcrops, it should have careful inspection before being adopted as a source of supply.

The North Branch is almost entirely undeveloped for water-power purposes. Near Ellisburg 20 feet fall could be readily obtained, and the available power for

[a] Geol. Survey New Jersey, vol. 3, p. 255.

nine months would be 0.87 horsepower per foot fall. As good pondage could be obtained, this would give about 35 horsepower for twelve hours daily during nine months of the year. On the main creek at Haddonfield mills we estimate 1.35 horsepower per foot fall day and night for nine months. A corn mill was erected on this site as early as 1697.[a]

Big Timber Creek empties into the Delaware at Gloucester. It drains an area of 59.03 square miles and is tidal to Good Intent. Its headwaters are on the Tertiary sands and gravels, and hence above Grenloch and Laurel Springs its branches would furnish fair local water supply. The New Jersey survey estimates the average flow of the creek at its mouth to be 55,400,000 gallons daily, and in the driest month 9,980,000 gallons daily.

In the table below are given the figures of aggregate flow of the Coastal Plain tributaries of the Delaware between Camden and Bridgeton.

Flow of tributaries of the Delaware—Camden to Bridgeton.[b]

	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
AVERAGE YEAR.													
Inches of rainfall	3.72	3.62	3.44	3.72	3.62	4.04	4.04	4.22	4.58	3.72	3.44	3.72	45.88
Inches flowing off	[c]1.70	2.90	2.71	2.75	2.22	1.92	1.13	.87	.79	.78	.84	1.00	19.61
Flow in 1,000 gallons daily per square mile	952	1,625	1,620	1,540	1,280	1,070	655	487	442	452	471	579	933
Horsepower per 1 foot fall per square mile	0.168	0.286	0.285	0.271	0.226	0.189	0.115	0.086	0.078	0.079	0.083	0.102	0.165
ORDINARY DRY YEAR.													
Inches of rainfall	4.04	4.12	1.71	3.02	2.67	3.44	3.82	4.55	4.00	1.01	2.14	2.28	36.80
Inches flowing off	3.11	3.35	1.17	2.13	2.05	1.33	.96	.85	.72	.46	.38	.47	16.98
Flow in 1,000 gallons daily per square mile	1,740	1,870	700	1,190	1,185	745	555	532	403	266	213	272	808
Horsepower per 1 foot fall per square mile	0.307	0.330	0.123	0.210	0.209	0.131	0.098	0.084	0.070	0.047	0.037	0.048	0.143
DRIEST PERIOD.													
Inches of rainfall	4.05	3.66	4.76	3.83	0.61	2.71	3.87	0.96	1.18	0.94	3.04	2.02	31.63
Inches flowing off	3.10	2.93	3.87	2.85	1.46	.91	.84	.46	.30	.30	.30	.30	17.62
Flow in 1,000 gallons daily per square mile	1,735	1,640	2,315	1,595	845	510	486	257	168	173	168	173	837
Horsepower per 1 foot fall per square mile	0.306	0.289	0.406	0.281	0.149	0.089	0.086	0.045	0.030	0.031	0.030	0.031	0.148
DRIEST PERIOD FOR TWO YEARS.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	0.99	46.24
Inches flowing off	.30	.47	.87	1.46	1.66	1.45	.96	.58	.40	2.32	1.63	.98	13.08

[a] Geol. Survey of New Jersey, op. cit. pp. 256–261.

[b] Op. cit., p. 257.

[c] The ground water is depleted at the end of the average year 1.12 inches, and this is deducted from the December flow.

The New Jersey survey makes the following report upon the water supply and water power of Big Timber Creek:

Above Clementon the watershed of the North Branch is 5.5 square miles, which will yield in the driest months 925,000 gallons daily without storage. With 3.28 inches storage 2,620,000 gallons daily may be obtained. The South Branch, above Grenloch, or Spring Mills, drains 15.5 square miles, and will yield, in the driest month, 2,610,000 gallons daily, or, with 3.28 inches storage, 7,400,000 gallons daily. The portion of the headwaters of Big Timber Creek suitable for water supply embraces in all 23 square miles, at an elevation of about 40 feet, with a capacity of 14,700,000 gallons daily with storage.

Such watersheds might be utilized to supply some of the towns near at hand, but they should be controlled by purchases of land bordering the streams. * * * These headwaters, while they are naturally quite secure from contamination, partake of some of the acid character of southern New Jersey streams, although generally in a less degree. They are generally free from the brown color of cedar swamp streams.

The power of Big Timber Creek is well utilized, although the fall is not large. At Grenloch we estimate 1.8 horsepower per foot fall for nine months. The only undeveloped site of any importance seems to be near the upper bridge at Chews Landing, on the North Branch, where 30 feet fall and good pondage could be had, although this would destroy the power at Laurel Mills. We estimate for this point 1.35 horsepower per foot fall, which would give on 30 feet fall 40 horsepower day and night, or 80 horsepower for twelve hours during nine months of the year, with a minimum of 34 horsepower for twelve hours.

Woodbury Creek empties into the Delaware northwest of Woodbury. It is more than 7 miles long and is a tidal stream for more than half its length and lies wholly upon the marls and clays, hence it can not be utilized for domestic supply or water power.

Mantua Creek empties into the Delaware at Paulsboro. It heads in Tertiary sands, but for the most part it flows upon the marls, and its water is unfit for domestic supply. Woodbury is supplied from its headwaters. The stream drains an area of 51.2 square miles. Above Hurffville the New Jersey survey estimates that its watershed has an area of 13 square miles and that the flow for the driest month is 2,180,000 gallons daily. With 3.28 inches storage 6,400,000 gallons could be obtained.

Above the pond, near Pitman Grove, Chestnut Branch has a drainage area of 4.4 square miles and a daily flow for the driest month of 740,000 gallons, while 2,090,000 gallons could be obtained with storage.

While there may be some other small branches which would afford good supplies of a limited amount, the rest of the watershed is open to suspicion and should not be accepted without careful examination.

The stream does not offer large opportunity for the development of water power, but near Mantua it would seem possible to develop 20 feet of fall with excellent pondage. We estimate for this point an available power of 2.3 horsepower per foot fall day and night.

Raccoon Creek empties into the Delaware northwest of Bridgeport. It is navigable to Swedesboro and is tidal for more than half its length. The headwaters of the main stream are in Tertiary sands, but the remainder of its course is almost entirely in the marls, and the stream can not be used for domestic supply.

The water powers developed are generally small, and the only opportunity for further development is at the first bridge above Swedesboro, where 20 feet fall could be obtained without interfering with existing mill sites. Its available power here would be 1.64 horsepower per foot fall, making 32.8 horsepower continuous, or 66 horsepower for twelve hours, with a minimum of 28 horsepower for twelve hours.

Oldmans Creek empties into the Delaware in the southwest corner of the Philadelphia district. Nine miles southeast of the Philadelphia district, above Harrisonville, its headwaters drain the Tertiary sands and might furnish a good water supply. The area of this portion of its watershed has been estimated as 10 square miles and the daily flow for the driest month as 1,680,000 gallons, which, with storage, could be raised to 4,760,000 daily. There is still some undeveloped fall below Harrisonville, but the power of the stream is small.

The following estimates have been made by the New Jersey survey of the area, percentage of forests, and population on these creeks:[a]

Area, percentage of forest, and density of population of watersheds of Coastal Plain tributaries of Delaware River.

Creek.	Area of drainage basin.	Percentage of forest.	Population per square mile.
	Sq. miles.		
Big Timber Creek	59.3	25	83
North Branch of Big Timber Creek	19.8	27	68
South Branch of Big Timber Creek	25.5	27	62
Cooper Creek	40.5	16	208
North Branch of Cooper Creek	11.7	16	65
South Branch of Cooper Creek	18.1	21	62
Mantua Creek	51.2	16	106
Mantua Creek above Berkeley	46.7	17	83
Pensauken Creek	35.4	10	109
North Branch of Pensauken Creek	17.1	7	71
South Branch of Pensauken Creek	14.9	12	118
Raccoon Creek	44.4	12	91
Raccoon Creek above Swedesboro	32.2	12	68
Raccoon Creek above Mullica Hill	13.1		
Oldmans Creek	44.4	14	52
Oldmans Creek above Auburn	26.3	18	46

[a] Op. cit., Appendix II, p. 56.

WATER POWER.

The following estimates have been made of the total fall, length, and average fall per mile of the creeks of the Philadelphia Coastal Plain district.

Length and fall of creeks in Coastal Plain portion of Philadelphia district.

Creek.	Length.	Fall.	Average fall per mile.
	Miles.	*Feet.*	*Feet.*
Big Timber	12½–13	130	10⅖
Cooper	12	130	10
Mantua	13	100	6¼
Oldmans	14	119	8
Pensauken	10	70	7
Raccoon	16	122	8
Woodbury	17	60	8⁴⁄₇

The water power utilized on these creeks has been tabulated as follows by the New Jersey survey:[a]

Water power utilized on the creeks in Coastal Plain portion of Philadelphia district.

COOPER CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Horsepower utilized. Net.	Horsepower utilized. Gross.
				Feet.		
North Branch	Marlton, Camden County.	Hopkins estate	Grist	12	[b] 8	([b])
Cooper Creek	Haddonfield, Camden County.	Jos. G. Evans	do	11	30	43
Do	Kirkwood, Camden County.	Knickerbocker Ice Co.	do	18	50	70
Do	Gibbsboro, Camden County.	Lucas	do	8	30	45
Do	do	Blakely	Saw	8	20	33
Haddonfield Branch.	Haddonfield, Camden County.	Hopkins estate	Grist	22	([b])	([b])
Tindale Run	do	Wilson Ice Co		15	([b])	([b])
Branch	Near Ashland, Camden County.	Joseph Kay	Gristmill site	24	([b])	([b])

NEWTON CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Net.	Gross.
Main Branch	Cuthberts, Camden County.	J. J. Schuetzius	Flouring	14	30	45
Do	Westmont, Camden County.	James Flynn	Paint and varnish.	15	22	51

[a] Op. cit., Appendix I, pp. 37–39. [b] Not in use.

Water power utilized on the creeks in Coastal Plain, etc.—Continued.

BIG TIMBER CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Horsepower utilized.	
					Net.	Gross.
				Feet.		
Little Timber Creek.	Near Asbury station, Gloucester County.	H. B. Hendrickson	Saw and distilling.	10	20	30
North Branch	Laurel Mills, Camden County.	E. Tomlinson	Grist	12	50	70
Do	Clementon, Camden County.	Theodore Gibbs	do	10	36	60
Almonesson Creek.	Almonesson, Gloucester County.	John Kennedy	do	18	35	50
South Branch	Good Intent, Camden County	J. Livermore and others.	do	11	22	30
Do	Grenloch, Camden County.	E. S. and F. Bateman.	Agricultural implements	14	100	145
Do	Prosser's mills, Gloucester County.	Thos. Boody	Grist	10	25	45
Do	Turnersville, Gloucester County.	——— Turner	Saw	10	14	20
Little Lebanon	do	A. W. Nash	Grist	10	36	50
Do	Near Turnersville, Gloucester County.	J. Prosser	Saw	10	32	45

MANTUA CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Net.	Gross.
Mantua Creek	Near Hurffville, Gloucester County.	S. O. Bricket	Grist	13	25	42
Do	Dilkesboro, Gloucester County.	Thos. Reeves	do	15	25	42
Edwards Run	Near Mantua, Gloucester County.	Chas. Jessop	do	12	30	42
Do	do	Sam. Boody	do	12	15	25
Chestnut Branch	Near Bornsboro, Gloucester County.	P. Avis	do	15½	20	28
Do	Pitman Grove, Gloucester County.	G. W. Carr	Saw, sash, and blind.	6	30	45
Wenonah Branch	Near Wenonah, Gloucester County.	The Wenonah Water Co.	Creamery	17	4	6
Monongahela Branch.	do	do	Mill site	10	a 15	(a)
Dilkesboro Branch.	Dilkesboro, Gloucester County.	W. Jessop	Saw	10	15	20

a Not in use.

REPAUPO CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Net.	Gross.
Purgey Brook	Tomlins station, Gloucester County.	S. Warrington	Grist	13	24	35

RACCOON CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Net.	Gross.
Raccoon Creek	Mullica Hill, Gloucester County	J. Mount	Grist	12	30	45
Do	Evans Mill, Gloucester County.	D. B. Brown	do	10	20	35
Swedesboro Branch.	Swedesboro, Gloucester County.	B. H. Black	Flouring	18	50	70
Do	Near Swedesboro, Gloucester County.	David Russell	Grist	15	25	42

Water power utilized on the creeks in Coastal Plain, etc.—Continued.

OLDMANS CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Horsepower utilized.	
					Net.	Gross.
				Feet.		
Oldmans Creek	Harrisonville, Salem County.		Grist	16	50	75
Do	Avis Mills, Salem County.	P. H. Avis & Son	do	12	30	45
Do	do	do	Saw	12	10	15
Do	Branch near Harrisonville station, Gloucester County.	Geo. Robinson	Grist	16	18	24
Do	do	—— Vanderbilt	do	20	12	20

PONDS.

The Philadelphia district, situated, as it is, to the south of the glaciated country and possessing a well-established drainage system, is free from natural ponds. The ponds that exist are insignificant and occupy artificial basins. The streams are thus without natural storage basins.

SPRINGS.

Between the members of the pre-Paleozoic and Paleozoic series and between the beds of the Wissahickon gneiss, which show considerable lithologic variation, springs emerge on the hillsides. Every farmhouse is supplied with spring water. The most copious spring of the region is one that issues from the base of the limestone at Spring Mill. A stream of such volume arises from this spring, which is not more than a quarter of a mile from the Schuylkill River, as to furnish water power for mills which were formerly situated upon it. There is a fine spring emerging near the base of the quartzite of the north Chester Valley hills in the gorge of Valley Creek. The springs are for the most part not deep seated, but surface springs which fluctuate more or less with the seasons. There are therefore no thermal springs, and no medicinal springs, so called, have been exploited in this region.

The springs of the Triassic area, with some exceptions, and of the formations of the Coastal Plain are small and of little value.

DEEP AND ARTESIAN WELLS.

PIEDMONT DISTRICT.

ANCIENT CRYSTALLINE BELT.

Numerous successful artesian wells have been bored in the pre-Paleozoic and Paleozoic rocks. Records have been obtained of the more important wells. In the pre-Georgian Schuylkill gneiss and a gabbro intrusive in it two wells have been bored, as follows: At Wayne a well 150 feet deep yields about 200 gallons per minute. At Radnor station there is an artesian well on the property of the Pennsylvania Railroad which furnishes water for locomotive purposes. It is located on the Schuylkill gneiss and gabbro intrusive. The well is 12 inches in diameter and 1,000 feet in depth, but is worked only to a depth of 120 feet, yielding at this depth, by the pneumatic system of pumping, 60 gallons per minute.

The following wells obtain water from the Chickies quartzite:

Wells bored in Chickies quartzite.

Locality.	Depth.	Water supply per minute.
	Feet.	*Gallons.*
Willow Grove	780	100
Near Fort Washington, J. Conrad	64	10
Waverly Heights, Edge Hill	570	([a])
Near Williams station	132	5

[a] No water.

Artesian wells in Chester Valley limestone.

Location.	Depth.	Water supply per minute.
	Feet.	*Gallons.*
Near Flourtown, Kunkle's farm	60	[a] 83⅓
Near Lancasterville, H. F. Hallman	98	10
Near King of Prussia, Wm. Thomas	90	-------
Near Williams station, Thomas Phipps	43	900

[a] Highly magnesian.

On the southeast slope of the south Chester Valley hills numerous wells have been bored for private individuals. These wells penetrated the mica-schist of the hills. They vary in depth from 60 to 80 feet and supply abundant water. In the shallow wells the water is soft; from the deeper wells it is reported to be hard. The thickness of the mica-schist is not very great on the slope of the hill, and possibly the water of the harder wells has its source in the top of the limestone horizon.

In the neighborhood of Bryn Mawr there are several artesian wells in the Wissahickon gneiss. The location, depths, and water supply of those of which a record has been obtained are as follows:

Wells in Wissahickon gneiss near Bryn Mawr.

Location.	Depth.	Diameter of bore.	Water supply per minute.
	Feet.	*Inches.*	*Gallons.*
Barrett Ice Plant (600 feet west of Bryn Mawr avenue, on County Line road), 2 wells	475	--------	60
	725	--------	10
Bryn Mawr Hospital	135	--------	5+
Bryn Mawr Hotel, 2 wells	350	10	50
	389	8	60
Springfield Water Company station at Bryn Mawr	560	6	83⅓

The continuation of the same belt of gneiss to the northeast furnishes artesian wells in the neighborhood of Jenkintown. One-third of a mile north of the station in Wyncote there are eight artesian wells and a pumping station. These wells furnish the water supply to those parts of Jenkintown not supplied by the North Springfield Water Company. They are less than 100 feet apart. The best flow is at 100 feet, and the flow increases with use. Their depth and water supply are as follows:

Wells at Wyncote.

	Depth.	Water supply per minute.
	Feet.	*Gallons.*
A	154	97
B	205	60
C	212	76
D	188	70
E	147	78
F	235	30
G	175	50
H	200	28

The following wells are also in the Wissahickon mica-gneiss:

Wells in Wissahickon mica-gneiss.

Location.	Depth.	Diameter of bore.	Water supply per minute.
	Feet.	*Inches.*	*Gallons.*
Jenkintown	349 324	6	75 75
At Jenkintown station	150		
Cheltenham Academy	352		12
Chelten Hills station	118		3
Oak Lane	125 340	8	1 [a] 208
Noble station	163		16
Overbrook, 3 wells	150	6	500
F. P. Hayes, Overbrook	240		10

[a] Hardness, 5.29.

There are a number of artesian wells in Philadelphia which have penetrated the rock floor of the Paleozoic crystallines and which are not tabulated with the Coastal Plain wells. These are as follows:

List of wells in Philadelphia and vicinity obtaining supplies from crystalline belt.

Location.	Depth.	Size.	Capacity per minute.
	Feet.	*Inches.*	*Gallons.*
Fairmount Company ice works, 2401 Green street	300	8	120
Schemm's brewery, Twentieth and Poplar streets	252	8	[a] 60
J. Bower & Company, packing house, Twenty-fourth and Brown streets	495	6	60
Thirteenth and Mount Vernon streets	2,031	8	[b] 50
Brewery, 1707 North Twelfth street	350	8	100
Seventh and Callowhill streets	452	8	150
Brewery, 1729 Mervine street	340	8	75
Prospect Brewery, corner Eleventh and Oxford streets	350	8	[a] 75
Crown and Willow streets	1,000	10	100
Ice works, 23 North Eleventh street	250	8	300
Wall paper, 2228 North Tenth street	210	8	100
Fifteenth and Market streets	500	8	100
Woolen mills, Ninth and Dauphin streets	272	6	30
Carpet works, Eleventh and Cambria streets	200	6	50
Dye works, 4520 Worth street, Frankford	335	6	250
Continental Hotel, corner Ninth and Chestnut streets	240	8	40
Hotel, Eleventh and Pine streets	576	5	[c] 40
Hotel, 108 South Broad street	484	8	60
Hotel, Broad street below Locust	525	8	70
Turkish bath, 1104 Walnut street	265	8	110
Machine shop, Fifty-second and Lancaster avenue	100	6	200
Morocco works, Frankford and Junction streets	500	6	500
Do	322	6	500
Do	252	6	500
Children's Home, 170 feet above tide, west of Georges Hill	364	8	[a] 60
Angora Cotton Factory	252	8	[a] 60
Vicker residence, Clifton Heights	30	5	100
N. & G. Taylor, southeastern part of the city	670	12	250
Morris and Otsego streets	140	--------	--------
Laurel and Beech streets	308	--------	--------

[a] Flowing wells. [b] Water not good in boilers. [c] Lime and iron water.

TRIASSIC BELT.

The three lowest divisions of the Triassic shales cover, as has been indicated, the greater part of the northern third of the Philadelphia district. Their interbedded sandstones offer favorable conditions for artesian wells. The water supply of this area is, in fact, largely furnished by such wells. Below is a list of those from which reports were obtained:

Artesian wells in Triassic rocks.

Locality.	Depth.	Depth to water.	Geologic horizon.	Water supply per hour.
	Feet.	*Feet.*		*Gallons.*
Norristown (Sandy Hill)	169	74	Sandstone bed in Norristown shale.	900
Norristown (near Stony Creek)	102		do	1,003
Norristown	100	16	do	3,000
Between Norristown and Jeffersonville, West End Land Co.	75		do	1,500
Jeffersonville, F. A. Poth	92½		Two sandstone horizons in Norristown shale, 35 to 40; 86 to 92½.	1,200
Hickorytown	70	45	Sandstone bed in Norristown shale.	600
Bridgeport, Charles Meyers	65		do	600
Sandy Hill schoolhouse, Whitepain Township.	60	28	do	120
Washington Square	35	11	Sandstone horizons of the Norristown shale.	1,500
Washington Square schoolhouse.	38½	14	do	600
Belfry station, Stony Creek R. R.	37	15	do	30
Ambler (3)	275		Abandoned; Cambro-Ordovician limestone (?).	2,100
Shady Grove schoolhouse, near Skippack pike and Morris road.	45	19	Probably sandstone of the Gwynedd series.	900
North Wales			Sandstone of the Gwynedd shale.	([a])
Lansdale	159	140	Sandstone horizons of the Lansdale shale series.	12,000
Do	376			
Do	611			
Southwest of Lansdale	65	15	do	60

[a] Very hard.

COASTAL PLAIN DISTRICT.

The water supplies of this district, except at Woodbury and Haddonfield, where water is obtained from streams, are derived almost entirely from artesian wells. This is due in part to the unsatisfactory quality of the water of the streams and in part to the ease and certainty with which artesian waters can be obtained.

GEOLOGIC CONDITIONS.

In a broad way the Coastal Plain may be said to be made up of beds of marl, clays, sands, and gravel, sloping somewhat rapidly to the east and southeast, and resting on a floor of the crystalline rocks with a similar or slightly greater dip. (See Pl. IV.)

The beds outcropping in the Philadelphia district may be classified geologically as follows, the oldest bed being at the bottom and the youngest at the top:

- Quaternary: Sand and gravel.
- Tertiary: Sand and gravel.
- Cretaceous:
  - Manasquan or upper marls.
  - Rancocas or middle marls.
  - Monmouth or lower marls.
  - Matawan or clay marls.
  - Raritan or plastic clay.

WATER HORIZONS.

At the outcrops of the more porous of these beds large quantities of water are absorbed, and there being no outlet to the east the sands and gravels have become saturated by water that is under considerable pressure. When wells penetrate such beds the waters rise, and if the mouth of the well is lower than the outcrop where the water enters, the wells overflow.

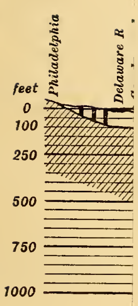
The wells in the principal water horizons in the Coastal Plain of the Philadelphia district are listed below.[a]

The Paleozoic crystallines which underlie the Cretaceous, Tertiary, and Quaternary deposits are reached by wells in the Delaware Valley and yield excellent water. The following wells gain their water supply from the crystalline rocks:

Wells obtaining water from crystalline rocks.

Locality.	Depth.	Remarks.
	Feet.	
Camden, near Front and Elm streets	$115\frac{1}{6}$	Reached rock at 95 feet.
Cramer Hill Ferry, 2 wells	116	In gneiss after 115 feet.
	126	On rock floor.
Delair	188	In gneiss after 168 feet.
United States Navy-Yard, League Island, Philadelphia.	906	260 to 906 in gneiss; water at 536 feet.
Do	600	270 to 600 in gneiss; water at 572 feet.
Near Grays Ferry	232	95 to 232 in gneiss.

[a] Data obtained mainly from the reports of the New Jersey geological survey, 1878-1902.


Philadelphia
Delaware R
feet
0
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250
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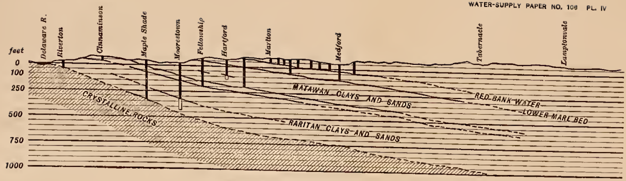
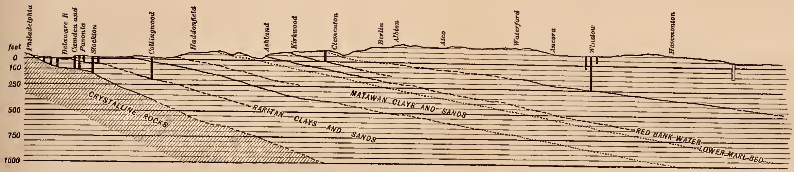
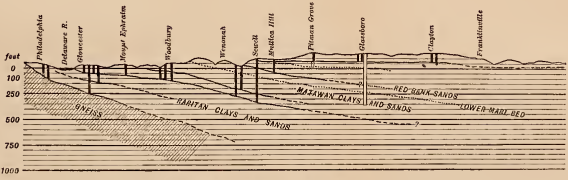


Sec. A. Delaware River through Maple Shade to central New Jersey.



Sec. B. Philadelphia through Ashland to south central New Jersey.



Sec. C. Philadelphia through Sewell to southern New Jersey.

SECTIONS SHOWING WATER HORIZONS ALONG WESTERN BORDER OF COASTAL PLAIN IN NEW JERSEY

(From Bull. U. S. Geol. Survey No. 138, Pl. III.)

At the base of the Raritan are heavy, yellowish white gravel and cobble strata. This horizon is reached by the following wells at the depths indicated:

Wells obtaining water from basal portion of Raritan formation.

Locality.	Depth.	Remarks.
Camden:	*Feet.*	
Esterbrook well	87	Fair supply.
Cooper Hospital	129	25,000 gallons per day.
Pumping station	98	
American Nickel Works	105	
Power house, Camden R. R. Co	147	
East of City Hall	72	
United States Chemical Works	134	
County prison	157	
Reeves Oilcloth Works, Twelfth and Pine streets.	93½	
Foot of Penn street	76	300 gallons per minute.
Delair, 2 wells	101, 118	Fair supply.
Gloucester	275	
Do	167	
Do	178	
Maple Shade	375	Abundant water.
National Park, below Red Bank, on Schuylkill.	80	
Pavonia, at Pennsylvania R. R, 4 wells	152, 174 154 124	Large supply.
Philadelphia:		
Little Dock street	96	
Moore street, on Delaware	150	
Riverton	50	10 gallons per minute.
Stockton	125	500 gallons per minute.
Washington Park, on Delaware	290	Ferruginous.

To this list should be added the wells in the southern portion of Philadelphia, which reach the horizon at an average depth of 130 feet and obtain large supplies of water.

Interstratified with the clays of the Raritan are local beds of coarse sand or gravel which are water bearing. Where they occur water may be reached at a less depth than that of the basal beds of the Raritan. The following wells have obtained water from horizons in the Raritan above the basal beds:

Wells obtaining water from Raritan formation above the basal beds.

Locality.	Depth.	Remarks.
	Feet.	
Camden Pen Works	67	
Collingswood	195	Good supply.
Delair	75	
Gloucester, 3 wells	149–162	200 gallons per minute.
Maple Shade	260–300	Excellent water.
Pavonia, 3 wells	67– 82	275 gallons per minute.
Riverton	50	10 gallons per minute.
Stockton	68	125 gallons per minute.

South and east of Philadelphia many wells obtain a large amount of fine water from bluish white gravels at the top of the Raritan. The following are the wells which gain their supply from this horizon:

Wells obtaining water from top of Raritan formation.

Locality	Depth.	Remarks.
	Feet.	
Audubon, 4½ miles southeast of Kaighns Point.	96	
Billingsport	67	Rises to surface.
Camden Dye Works, Eighth and Spruce streets.	183	
United States Chemical Works	47	
Camden, Haddon Avenue station, 3 wells	75 92 105	Rises to within 15 feet of surface. Water horizons at 75 and 92 feet.
Seventeenth and Stevens streets	81	250 gallons per minute.
Cinnaminson	46	450 gallons per minute.
Clarksboro, 2 wells	178 180	
Collingswood	105	Water not reported.
Fish House, 2 wells	105 119	15 gallons per minute. 40 gallons per minute.
Gloucester, 13 wells	64–102	Large supply.
Magnolia	330	
Maple Shade	130	Considerable water.
½ mile northeast of Mickleton	183	Water soft and good.
Mickleton	238	Good water.
Morris Station, 100 and more wells	50–150	From two horizons in the Raritan.
2 miles south of Mount Ephraim	134	Satisfactory.
1 mile south of Mount Ephraim	215	

Wells obtaining water from top of Raritan formation—Continued.

Locality.	Depth.	Remarks.
	Feet.	
Hedding Church	211	Fine well.
National Park below Red Bank, on Delaware.	78	
West Palmyra, 4 wells	30– 46	
½ mile west of Paulsboro	66	
Paulsboro, a number of wells	30– 60	
¾ of a mile southeast of Pedricktown	180	
1½ miles northwest of Pedricktown	24 24 24	
Philadelphia:		
Seventeenth street and Washington avenue.	67	
Eighth and Catherine streets	92	
Point Breeze Gas Works	96	
Atlantic Refinery	56	
Spreckles Sugarhouse	89	
Reed Street wharf	98	
1½ miles east of Riverton	117	
Sewell	420	25 gallons per minute.
Swedesboro	172	Good water.
Do	130	
Do	133	15 gallons per minute.
Thorofare	146	
1 mile west of Thorofare	60	
Washington Park on Delaware, 2 wells	82 92	
Wenonah	320–341	40 gallons per minute.
Westville	241	Abundant water, but not ferruginous.
Do	112	
Do	114	
Do	105	
South Westville	118	
Woodbury, several wells	104–163	Variable amounts.
1 mile north of Woodbury	68	8 gallons per minute.
1 mile south of Woodbury	130	
North Woodbury	128	
1 mile south of Woodbury	130	
North Woodbury	128	

South and east of the Philadelphia district a few wells derive their water supply from some coarse sand and gravel beds within the Matawan and above the basal beds. The basal Matawan and deeper horizons furnish a more satisfactory supply. The following are the wells:

Wells obtaining water from middle portion of Matawan formation.

Locality.	Depth.	Remarks.
	Feet.	
Blackwood	70	
Do	68	
Clarksboro	90	
¾ of a mile northwest of Kirkwood	129	
Laurel Springs, 3 wells	73 83 103	
Maple Shade	64–97	Considerable.
⅞ of a mile southeast of Merchantville	65	
1¼ miles southeast of Merchantville	58	
4 miles west of Mickleton	43	Good water.
Newbold	73	
2 miles southeast of Paulsboro	114	Satisfactory.
Sewell	342–351	Small amount.
Stratford	107	
Thorofare	35	Ferruginous.
Do	67	Do.
Wenonah Waterworks	196	Satisfactory.
South Westville	59	
Woodbury	80	Fair fupply.
2 miles south of Woodbury	120	Satisfactory.

Many of the best wells in southern New Jersey obtain their water supply from the Mount Laurel sands at the base of the Monmouth formation, but not many are within the Philadelphia district. Water from this horizon might be expected at Sewell and Wenonah, but none has been reported.

Wells obtaining water from the base of the Monmouth.

	Feet.
Blackwood	70
Do	68
Laurel Springs, 2 wells	73–83
Do	103

A well at Sewell derives water from the red sand that lies between the Monmouth and the Rancocas formations, at a depth of 72 feet.

The wells listed below gain their water supply from the bryozoan earth within the Rancocas:

Wells from Rancocas horizon.

	Feet.
Laurel Springs	45
At hotel	73
Laurel Springs	48
Laurel Springs:	
7 wells	48–56
6 wells	48–50

No wells have been reported at the base of the Tertiary in the Philadelphia district. This and other Tertiary horizons are exceedingly important elsewhere in southeastern New Jersey.

Following is an alphabetical list of artesian wells embracing all geologic horizons in the Coastal Plain of the Philadelphia district. It was compiled from the well records in the reports of the geological survey of New Jersey, 1878–1902.

Deep wells in Coastal Plain of the Philadelphia district.

Location.	Depth.	Bore.	Capacity per minute.	Height of water above (+) or below (−) curb.	Geologic horizon.	Remarks.
	Feet.	*Ins.*	*Gals.*	*Feet.*		
Audubon, 4½ miles southeast of Kaighns Point, Camden.	96	6	42		Top of Raritan	
Barnsboro	110	3	} 54		Basal Matawan	
Do	170	3				
Near Barnsboro	140	3	350		do	
In northwest of Barnsboro.	318½	4	70		do	
Billingsport	67	3		Surface	In Raritan	
Blackwood	70	3				
Camden	68	3			Top of Matawan	
Esterbrook Pen Co	62–87	6	70	−5	Basal Raritan	Clay particles in water.
Cooper Hospital	129	6	16	−16	do	
Camden Ice Co., 2 wells.	152	8	150		do	
Camden pumping station.	112	6			do	
Front and Elm streets	115⅙	3			Gneiss at 95 feet	
Seventh and Kaighn avenue.	90 7/12					
Do	101 5/12				Raritan	Satisfactory.
Haddon Avenue station.	75	2				
Do	92	2		−15	Water at 75 to 92 feet.	
Do	105	2			Basal Matawan	
American Nickel Works.	105	6		Tide level	Basal Raritan after 86 feet in gneiss.	
Foot of Cooke street, ammonia works.	105				Water at 59 to 62 feet, basal Raritan.	
Power house, Camden R. R. Co.	147	6			Basal Raritan	
East of City Hall	72	4½			do	
United States Chemical Works.	134				Upper Raritan	
Do	47					

Deep wells in Coastal Plain of the Philadelphia district—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height of water above (+) or below (−) curb.	Geologic horizon.	Remarks.
Camden—Continued.	*Feet.*	*Ins.*	*Gals.*	*Feet.*		
County prison	157	6			In gneiss, basal Raritan.	
Reeve's Oilcloth Works, Twelfth and Pine streets.	93½	6	16		In Raritan, probably basal.	
Foot of Penn street	76	8	300		Basal Raritan	
Seventeenth and Stevens streets.	81	42	250		In Raritan	
Camden Dye Works, Eighth and Spruce streets.	183	6			do	
Cinnaminson	46	6	450		Basal Matawan	
Clarksboro	90				Matawan	
Do	180	3	70		Top of Raritan	
Collingswood	196				In Raritan	
Cramer Hill Ferry	116				do	
Do	115	6		Surface	In gneiss	
Do	126	6			do	
Delair, north of	78			−40	In Raritan	
Do	118				do	
Do	188				In gneiss	
Do	101				do	
Do	162				In Raritan	
Fish house, 2 wells	105	8	15		do	
	119	8	40			
Gloucester	270		650	+1	Basal Raritan	
Gloucester, 7 wells	67–96	4½			Basal Matawan	
Gloucester, 3 wells	149–162	4½			In Raritan	
Gloucester, 6 wells	65–102	3			Basal Matawan	
Gloucester, 3 wells	84–88	3			In Raritan	
Gloucester	167	8		Overflows. Tidal rise of all, 18 inches.	Basal Raritan	
Do	97	8			Top of Raritan	
Do	178	8			Basal Raritan	
Do	82	8			Top of Raritan	
Hedding, 1 mile south of Mount Ephraim.	215	3			Basal Matawan	
Hedding Church	211		70		do	Fine well.
Merchantville Water Co., Jordantown (4 wells).	124–141	6	100		Raritan	Very satisfactory.
Kirkwood, ¾ mile northwest.	129	3	46		Top of Matawan	
Laurel Springs:						
7 wells northeast of railroad.	48–56	3			In Rancocas	
6 wells southwest of railroad.	48–50	3			do	
2 wells	73–83	3			Top of Matawan	
1 well	103	3	19		do	
Laurel Springs	45	3	10		In Rancocas, bryozoan earth.	
At hotel	73				In Rancocas	
Laurel Springs	148	3	18		do	
Magnolia	330				In Raritan	
Mantua	195	3	10		Basal Matawan	
Near Merchantville	130			−45	Matawan	Not very satisfactory.
2½ miles southwest of Merchantville, S. F. Starr.	251				Raritan	

Deep wells in Coastal Plain of the Philadelphia district—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height of water above (+) or below (−) curb.	Geologic horizon.	Remarks.
	Feet.	*Ins.*	*Gals.*	*Feet.*		
⅞ mile southeast of Merchantville.	65				In Matawan	
1¼ miles southeast of Merchantville.	58				do	
Mickleton	238	3	61		Basal Matawan	Good water.
4 miles west of Mickleton	43	3	14		In Matawan	Soft and good.
½ mile northeast of Mickleton.	183	3	45		Top of Raritan	
Morris station wells, 100 and more.	50-150			Tide level; pulsates with tides.	From 2 horizons in Raritan.	
Mount Ephraim	130				Basal Matawan	Satisfactory.
Mount Ephraim, ¾ mile distant.	80				do	Do.
Mount Ephraim, 2 miles south.	134		44		do	Do.
National Park below Red Bank, on Delaware.	78	3	48		In Raritan	
Do	80	6			Basal Raritan	
Newbold	73	4	12		In Matawan	
2 miles east-southeast of West Palmyra, 4 wells.	30-46				In Pleistocene and Raritan.	
Paulsboro	114	4			In Matawan	Do.
Paulsboro, number of wells.	30-60				In Raritan	
½ mile west of Paulsboro	66		16		do	
3½ miles southwest of Paulsboro, E. G. Miller.	192				Raritan	
Pavonia	152				Basal Raritan	
3 wells	67-82		275		In Raritan	
1 well	174				Basal Raritan	
Do	112				To crystalline rock	
Pavonia	154	6-56	22½		Basal Raritan	
Pennsylvania R. R	124	2 below.	22½		do	
Pedricktown	180	2	30			
¾ mile southeast	24	3	6		In Raritan	
1½ miles northwest	24	3			do	
Do	24	3			do	
Philadelphia:						
Foot of Tioga street, 5 wells.	65	8			Alluvium, Raritan clays; gneiss not reached.	
Little Dock street	96				Basal Raritan	
Seventeenth and Washington avenue, Consumers' Ice Co.	67			−25	Raritan	
Eighth and Catharine	92				do	
Moore Street wharf on Delaware, Baugh Phosphate Co.	150	3		Tide level	Basal Raritan	
Point Breeze gas works	96				Raritan	
Atlantic Refinery, Point Breeze.	56				do	
Do	89					
United States Navy-Yard, League Island	600		25		Alluvium and Raritan.	Satisfactory; to gneiss, 270; in gneiss, 330.
Do	906	10	79-260		Raritan, 79-260; gneiss, 260-906.	
Do., several tests for.	25-38	4			Alluvium and Pleistocene.	

Deep wells in Coastal Plain of the Philadelphia district—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height of water above (+) or below (−) curb.	Geologic horizon.	Remarks.
	Feet.	*Ins.*	*Gals.*	*Feet.*		
Philadelphia—Continued.						
Hog Island, Delaware River.	456				Alluvium	
Spreckels's sugar house, Reed Street wharf.	98				In Raritan	
Near Grays Ferry, southern Philadelphia.	232	6				
Fifteenth and Callowhill streets.	26					
Fidelity Building, Broad street, near Arch.	46	8				
Do	42	10	300		Pleistocene sand (?)	
Riverton	50		10		In Raritan	
1½ miles east of Riverton	117		69		do	
Sewall	420	3	25		Basal Matawan	Also water in Redbank at 72 feet and in Matawan at 381-395 feet.
South Westville	118	4	23		do	
Do	59	3			In Matawan	
Swedesboro	172	3			Basal Matawan	Good.
Do	130	6	15	Overflows	Top of Raritan	
Do	133	6	15	do	do	
Do	133	6	15	do	do	
Do	70	3	15	do	Basal Raritan	
Thorofare	35	2½			In Matawan	Ferruginous.
Do	146	3			Basal Matawan	
Do	67	2½			In Matawan	Do.
1 mile west of Thorofare	60				Basal Matawan	
Tomlins	120	3	40		Top of Raritan	
Washington Park on Delaware.	82				Basal Matawan	
Do	92				do	Do.
Do	290			Tide level	Basal Raritan	
Wenonah	341			−40	Basal Matawan	
Westville	112	6	15		Basal Matawan	
Do	114	6			do	
Do	105	3	36		do	
Do	241	6			In Raritan	Abundant water, but of red color.
South Westville	118	4	23		Basal Matawan	
Do	59	3			In Matawan	
1 mile south of Woodbury	130				Basal Matawan	
Woodbury	80				In Matawan	Fair supply.
Do	163	4½			Basal Matawan	Few.
Do	132	4½	2		do	
Do	113	2½		−19	do	Fair supply.
Do	142		8	−50	do	
Do	136				do	
Woodbury, 1 mile north	68	4	8	−10	do	
Woodbury, 2 miles south	120				In Matawan	
North Woodbury	128	4	28		Basal Matawan	

PUBLIC WATER SUPPLIES.

The consumption of water by the cities and towns of the Philadelphia district is enormous, that of Philadelphia being said to surpass in per capita any other city in the United States. In the absence of conditions favorable to storage it is natural that the rivers should be resorted to by the larger communities. In the smaller towns and villages, however, where the demand is not so great, wells and springs sometimes constitute the principal supplies.

In the area of the crystalline rocks in Pennsylvania, Philadelphia and all considerable towns in the outskirts of Philadelphia, except Chester, Media, Tacony, Holmesburg, and Torresdale, are supplied by the Philadelphia bureau of water, the Springfield Water Company, and the North Springfield Water Company. The towns of Norristown and Ambler, in the belt of Triassic rocks, obtain their supplies from the Schuylkill River and from springs in the Norristown sandstone, respectively. In the Coastal Plain, Camden, Riverton, Palmyra, Newbold, Paulsboro, and other towns obtain their supplies mainly from artesian wells.

PHILADELPHIA AND SUBURBS.

PHILADELPHIA BUREAU OF WATER.

Philadelphia, Falls of Schuylkill, Manayunk, Roxboro, Chestnut Hill (in part), Mount Airy, Germantown, Frankford, Bridesburg, Wissinoming, and the intervening areas are supplied with water by the bureau of water of Philadelphia.

Water is pumped from the Schuylkill at five stations: (1) The Roxboro station, above Flat Rock dam, 1 mile southwest of Roxboro and north of Manayunk; (2) Queen Lane station, just north of Queen Lane; (3) Belmont station, at the bridge of the Pennsylvania Railroad, New York division; (4) Spring Garden; and (5) Fairmount station, at Fairmount dam. Water is also pumped from the Delaware at Frankford station, one-half mile northeast of the mouth of Wissinoming Creek. From these points it is pumped to reservoirs at Roxboro, Queen Lane, Fairmount Park, and Frankford, whence it has been distributed without filtration. A comprehensive system of plain sand filters is now being introduced. There are three plants, located at Roxboro, Bala (Belmont and City Line avenues), and Torresdale. Torresdale is situated on the Delaware at the mouth of Poquessing Creek, 2 miles northeast of Liddonfield and $1\frac{1}{8}$ miles beyond the limits of the Philadelphia district. At Torresdale water is to be taken from the Delaware, and after being passed through 65 sand filters is to be carried in a rock tunnel, 10 feet 7 inches in diameter and 100 feet below the surface, to Robbins street, Tacony, whence it is to be distributed to the Philadelphia district. The Roxboro district, comprising Roxboro, Manayunk, Chestnut Hill, Mount Airy, and Germantown (in part), is now supplied from the Roxboro filter plant, which is completed and in operation. The Queen Lane district, including the Falls of Schuylkill and Germantown (in part), Philadelphia, and the towns lying between Philadelphia and Torresdale, will be supplied from the Torresdale plant, which will not be in operation before 1906; while Overbrook and West Philadelphia are to be supplied from the Belmont plant, which will be completed this year.

The combined capacity of the filters is 320,000,000 gallons, or 30,000,000 gallons more than the capacity of the Croton Aqueduct. At present the per capita consumption of water in New York is 120 gallons daily, while in Philadelphia it is 229 gallons.

Under the present system there is pumped from the Schuylkill River for the city supply a daily average of 283,429,000 gallons, while the Delaware River furnishes 30,160,000 gallons, making a total of 313,589,000 gallons; thus the Schuylkill River furnishes over 90 per cent and the Delaware River the remainder. Under the new system the Schuylkill River will furnish about 20 per cent of the water consumed and the Delaware River 80 per cent.

The following tables, compiled from the report of Mr. John W. Hill, chief engineer of the bureau of filtration, indicate the relative merits of the two streams as a source of city water supply.

Turbidity in 1902, in parts per 1,000,000, by the silica standard.

	Maximum.	Minimum.	Average.
Delaware River	460	9	53
Schuylkill River	1,100	9	100

Bacteria per cubic centimeter in 1902.

	Maximum.	Minimum.	Average.
Delaware River	24,000	550	6,405
Schuylkill River	86,000	630	14,160

Hardness, equivalent to calcium carbonate.

	Maximum.	Minimum.	Average.
Delaware River	94	26	51
Schuylkill River	124	44	87

Color by the platinum-cobalt standard.

	Maximum.	Minimum.	Average.
Delaware River	0.40	0.10	0.19
Schuylkill River	0.22	0.04	0.09

These data are favorable to the Delaware River in all respects except color. The color of the water of the Delaware is due to the vegetable stain brought to it by some of its southern New Jersey tributaries. While it will probably not be removed by sand filters, it is not, on the other hand, known to be inimical to health.

SPRINGFIELD WATER COMPANIES.

The Springfield Water Company and the North Springfield Water Company, under the control of the American Pipe Manufacturing Company, supply most of the suburban districts with water.

All towns north of the Delaware and between Cobbs and Crum creeks, including Eddystone (west of Crum Creek), are supplied by the Springfield Water Company. The northern boundary of the area supplied by it extends from its reservoir, 1 mile southwest of Marple, eastward along the State road to Lansdowne avenue, thence northwest to Llanerch and to the junction of the Haverford and City Line roads, and east to the Schuylkill River. The towns along the main line of the Pennsylvania Railroad as far as Glen Loch, 25.3 miles from Philadelphia, are supplied by the Springfield and North Springfield Water companies, also the towns east of the main line—Conshohocken, Chestnut Hill (in part), Oreland, Glenside, Jenkintown (in part), Oak Lane, and the intervening towns. Bryn Mawr is on the dividing line between the northern portion of this district, which is supplied with water by the North Springfield Water Company, and the southern portion, which is supplied chiefly by the Springfield Water Company.

SPRINGFIELD WATER COMPANY.

The Springfield Water Company takes its water from Crum Creek 1½ miles northeast of Media, in the township of Springfield. The water is first coagulated with aluminum sulphate and passed into a sedimentation basin with 10,000,000 gallons capacity. From this basin it is passed into suction wells, and from these wells the water is pumped into six pressure filters, which have a capacity of 500,000 gallons each and which are rinsed out daily. There are reservoirs at Marple (321 feet above tide), at Secane (243.5 feet above tide), and at Overbrook (201 feet above tide), with capacities of 2,000,000, 4,000,000, and 3,000,000 gallons, respectively. The pumping station on Crum Creek has never been worked to its full capacity. The consumption of water at present does not exceed 2,000,000 gallons in twenty-four hours.

NORTH SPRINGFIELD WATER COMPANY.

The North Springfield Water Company takes its water from Pickering Creek, near its mouth. Here are located a pumping station, a sedimentation basin, and filters. There are three filters—one slow sand filter, covering one-half an acre, with a capacity of 1,500,000 gallons, and two gravity mechanical filters with a combined capacity of 2,500,000 gallons. The water is first pumped to a 10,000,000-gallon sedimentation reservoir, located across the creek from the pumping station. From the sedimentation basin the water gravitates through the filter plant to a 1,500,000-gallon clear-water basin and thence is pumped to the distributing reservoirs by means of two high-duty fly-wheel pumping engines. The three distributing reservoirs connected with this system are located at Diamond Rock (620 feet above tide), in the north Chester Valley hills, at a point about 1 mile southwest of Valley Forge on the same hills (586 feet above tide), and at Devon (549 feet above tide), with capacities, respectively, of 1,000,000, 2,000,000, and 4,000,000 gallons. There are standpipes also at Bryn Mawr (531 feet above tide), at Ardmore (400 feet above tide), at Conshohocken (246 feet above tide), at Chestnut Hill (505 feet above tide), and at Oak Lane (315 feet above tide). There are three artesian wells under the control of the North Springfield Water Company which can act as a reserve supply. One at Bryn Mawr, 560 feet deep, will furnish 120,000 gallons in twenty-four hours. Two at Oak Lane, 340 feet deep, will furnish 300,000 gallons in twenty-four hours. The water has a hardness of 5.5 in the Bryn Mawr well and of 5.29 in the Oak Lane wells. This means 5.5 parts of carbonate of lime in 100,000.

The consumption of water in this system does not exceed 2,000,000 gallons daily, while the sedimentation basin has a capacity of 10,000,000 gallons. There are over 300 miles of pipe under the control of the American Pipe Manufacturing Company, and that company is prepared to supply a much more densely populated district with abundant water.

The following analysis of the filtered water of Pickering Creek, made by M. P. Ravenel, State bacteriologist, shows it to be potable water:

Analysis of water of Pickering Creek.

	Per cent.
Free ammonia	0.08
Nitrogen as nitrates	1.33
Chlorine as chlorates	5.00
Alkalinity in terms of—	
Carbonate of lime	37.36
Hardness in terms of—	
Carbonate of lime	41.60
Number of bacteria exceedingly low.	

The analysis of Crum Creek water taken from the spigots is equally favorable.

INDEPENDENT COMPANIES.

Tacony, Holmesburg, and Torresdale, in the Thirty-fifth and Forty-first wards of Philadelphia, are supplied with water by a private company. The plant, which is owned by the Holmesburg Water Company and operated by the Disston Water Company as lessee, is located in Holmesburg near the mouth of Sandy Run. This little stream has its source in Fox Chase, is fed by springs along its course, and empties into the Pennypack at Holmesburg, somewhat more than 2 miles north of the Delaware. A mechanical system of filtration is in use, installed by the New York Continental Jewell Filtration Company and possessing a capacity of 2,000,000 gallons per day.

CHESTER.

The water supply for the city of Chester is taken from the Delaware River. It is pumped to a point 4 miles from Chester, to two reservoirs having a capacity of 8,000,000 gallons each. After it has settled it is passed through mechanical filters to a clear-water basin.

MEDIA.

The water department of the borough of Media supplies the city of Media with water. This company takes its water from Ridley Creek. The water is pumped through two sand filters to a reservoir and standpipe, whence it is supplied to the town. This plant furnishes 1,500,000 gallons every twenty-four hours.

NORRISTOWN.

Norristown is supplied with water by the Norristown Water Company. This company obtains its water supply from the Schuylkill. The pipes are laid under the river and draw their supply from the channel southwest of the island opposite Norristown. In this way contamination from Stony Creek, which carries the drainage of the State insane asylum, is avoided. The water is first pumped into a small settling basin, where it is coagulated by means of aluminum sulphate. It then filters by gravity through a 5,000,000-gallon filter plant and passes into a clear-water basin, from which it is pumped to the distributing reservoir located on the hill north of Norristown. This reservoir has a capacity of 11,000,000 gallons.

LANSDALE.

Lansdale obtains its water supply from two artesian wells, connected with a standpipe having a capacity of 38,000 gallons. The system is owned by the Lansdale Water Company.

AMBLER.

The Ambler Spring Water Company, which supplies Ambler, obtains very pure water from a large number of springs issuing from a sandstone bed of the Norristown formation. These springs furnish several hundred million gallons per annum. In addition, a large spring in a quarry in the Norristown formation is used, which yields about 15,000 gallons per hour.

CAMDEN.

For many years (since about 1853) Camden took its water from the Delaware River, southeast of Petty Island. The pumping station was located at Pavonia, northeast of the mouth of Cooper Creek. Because of the increasing impurity of the water the supply became very unsatisfactory, and in 1897 and 1898 more than 100 artesian wells were sunk near Morris station, which yield an abundance of pure water. These wells obtain their supply from two horizons within the Raritan. The deeper wells probably reach the base of the Raritan. All the wells are furnished with bottom strainers. A pumping station is established at this point, and over 20,000,000 gallons of water can be obtained every twenty-four hours.

RIVERTON AND PALMYRA.

The Riverton and Palmyra Water Company, which supplies these two towns, obtains its water from a dug well, 15 feet deep, near the Delaware River. The well is sunk in gravel and intercepts the water on its way to the river. This well yields 300,000 to 500,000 gallons per day and is estimated to have a capacity of 1,000,000 gallons per day.

HADDONFIELD.

The water supply of Haddonfield is obtained from a small tributary to the North Branch of Cooper Creek. This stream is fed by springs and furnishes 500,000 gallons per twenty-four hours. The water is pumped from a reservoir to a standpipe, whence it is distributed without filtration.

NEWBOLD AND WESTVILLE.

Newbold and Westville are supplied by the Westville-Newbold Water Company, which obtains water from three artesian wells, each 160 feet deep.

PAULSBORO.

Paulsboro obtains its water supply from artesian wells 65 feet deep, which yield 350 gallons per minute. No filter plant is required. The water is clear, colorless, and odorless, and analysis shows it to be remarkably pure.

OTHER TOWNS.

Water supply, consumption, etc., in other towns.

Town.	Water supply.	Population.	Daily consumption.	Treatment of water.
			Gallons.	
Gloucester	Open wells	6,564	1,000,000	None.
Merchantville	Springs	1,225	150,000	Do.
Red Bank	Open wells	4,125	150,000	Also tube wells.
Wenonah	do	500	25,000	Do.
Woodbury	Mantua Creek	3,911	225,500	Do.

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Author.

Bascom, Florence.

. . . Water resources of the Philadelphia district, by Florence Bascom. Washington, Gov't print. off., 1904.

75 p., 1 l. illus., 4 pl. (incl. map) 23^{cm}. (U. S. Geological survey. Water-supply and irrigation paper no. 106.)

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see also

U. S. Geological survey.

SERIES K—PUMPING WATER.

WS 1. Pumping water for irrigation, by H. M. Wilson. 1896. 57 pp., 9 pls.
WS 8. Windmills for irrigation, by E. C. Murphy. 1897. 49 pp., 8 pls.
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SERIES N—WATER POWER.

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The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Pt. II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Pt. II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Pt. II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Pt. IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Pt. IV; Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Pt. IV; Artesian well prospects in the Atlantic Coastal Plain region, by N. H. Darton, Bulletin No. 138.

Series P—Hydrographic Progress Reports.

Progress reports may be found in the following publications: For 1888-89, Tenth Annual, Pt. II; for 1889-90, Eleventh Annual, Pt. II; for 1890-91, Twelfth Annual, Pt. II; for 1891-92, Thirteenth Annual, Pt. III; for 1893-94, B 131; for 1895, B 140; for 1896, Eighteenth Annual, Pt. IV, WS 11; for 1897, Nineteenth Annual, Pt. IV, WS 15, 16; for 1898, Twentieth Annual, Pt. IV, WS 27, 28; for 1899, Twenty-first Annual, Pt. IV, WS 35-39; for 1901, Twenty-second Annual, Pt. IV, WS 47-52; for 1901, WS 65, 66, 75; for 1902, WS 82-85; for 1903, WS 97-100

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G. P. O., Apr., '05