Analysis of Stream-Temperature Variations in the Upper Delaware River Basin, New York

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1999-K

Prepared in cooperation with the Delaware River Basin Commission

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By OWEN O. WILLIAMS

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1971

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

W. A. Radlinski, *Acting Director*

Library of Congress catalog-card No. 71-611766

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ANALYSIS OF STREAM-TEMPERATURE VARIATIONS IN THE UPPER DELAWARE RIVER BASIN, NEW YORK

By Owen O. Williams

ABSTRACT

The effect of climatologic conditions and reservoir releases on downstream conditions was determined by means of statistical and graphical analyses of stream-temperature variations measured in the upper Delaware River basin, May–September 1964–67. Climatologic conditions normally increase water temperatures from February through July and decrease them from August through January. Summer releases from New York City's Cannonsville Reservoir were observed to decrease water temperatures by 13°C (Celsius) in 8.1 miles and by 1°C, 55.9 miles downstream from this reservoir. Releases from New York City's Pepacton Reservoir were observed to decrease water temperatures by 11°C in 31.0 miles and between 1°–3°C in 71.0 miles downstream from this reservoir. The influence of releases from these reservoirs is dependent upon five factors: Thermal stratification in the reservoir, depth at which water is withdrawn from the reservoir, rate of release, distance downstream from the reservoir, and climatologic conditions.

INTRODUCTION

In the spring of 1964, the U.S. Geological Survey and the Delaware River Basin Commission entered into a cooperative program to collect and report stream temperatures in the upper Delaware River basin. Collection of data was scheduled only during the summer months from 1964 through 1967. The objectives of this cooperative investigation were to: (1) Define the variations in water temperatures during the summer months, (2) determine the effect of reservoir releases on downstream water temperatures, and (3) provide data from which the thermal suitability of the study area as a spawning and nursery habitat for anadromous fish can be determined.

Stream temperatures always have been important to studies of water quality because many physical, chemical, and biological properties of water are expressed as functions of temperature. Their importance is more apparent now because of the increased awareness of the effect of thermal pollution upon ecology. This term "thermal pollution" usually is applied to influxes of thermally overloaded water. However, an influx of thermally depleted water can also be a form of thermal pollution and often has a marked effect on the stream's ecological system. Plant or animal life, which may have flourished in an area, can become scarce or even be eliminated if temperature requirements are not met. At the same time, other plant or animal life, which may have been scarce, may begin to flourish.

Influxes of thermally depleted water can result from reservoir releases made through a low-level outlet during summer months. Most large storage reservoirs exhibit the classical type of thermal stratification. Mackenthun, Ingram, and Porges (1964, p. 9–10) describe thermal stratification as follows:

> For a few weeks in the spring, water temperatures may be homogeneous from the top of a water body to the bottom. Vertical water density is also homogeneous and it becomes possible for the wind to mix the water in a lake * * * The advance of summer quickly checks circulation by warming the surface waters; as they warm they become lighter, resting over colder water of greater density. Thus, a permanent thermal stratification is formed. In natural deep bodies of water, three layers eventually form. The upper layer, or epilimnion, represents the warm, more or less freely circulating region of approximately uniform temperature, and may vary in thickness from 10 feet or less in shallow lakes to 40 feet or more in deeper ones. The middle layer, or thermocline, is the region of rapid change, usually defined by a change in temperature of 1.8° F (Fahrenheit) for each 3.28 feet variance in depth. The lower layer, or hypolimnion, is the cold region of approximately uniform depth. It is cut off from circulation with upper water.
>
> As autumn comes, the standing body of water cools; the epilimnion increases in thickness until the lake becomes homothermous, and again a period of complete circulation begins. This occurs from late September to December, depending upon the area and depth of the lake and its geographic and climatic location. It lasts until changes in density reestablish stratification, or until the lake is frozen over. This commonly occurs from November to January, varying with lake and season and geographic location. Circulation then ceases until spring.

If a storage reservoir is stratified in this manner and releases are made through a low-level outlet from the hypolimnion, the water being released will be colder than the normal stream temperature in the area. If the release is both significantly colder and significantly larger than the natural flow in the stream, the water temperature downstream from the reservoir may be lowered so that the temperature requirements of certain plant or animal life in the stream are not met.

GENERAL FEATURES OF THE STUDY AREA

The reach under study (fig. 1) extends 17.5 miles from Cannonsville Reservoir on the West Branch Delaware River to its confluence with the East Branch at Hancock; from Pepacton Reservoir on the East Branch, 32.6 miles to the confluence with the West Branch; and 54.5

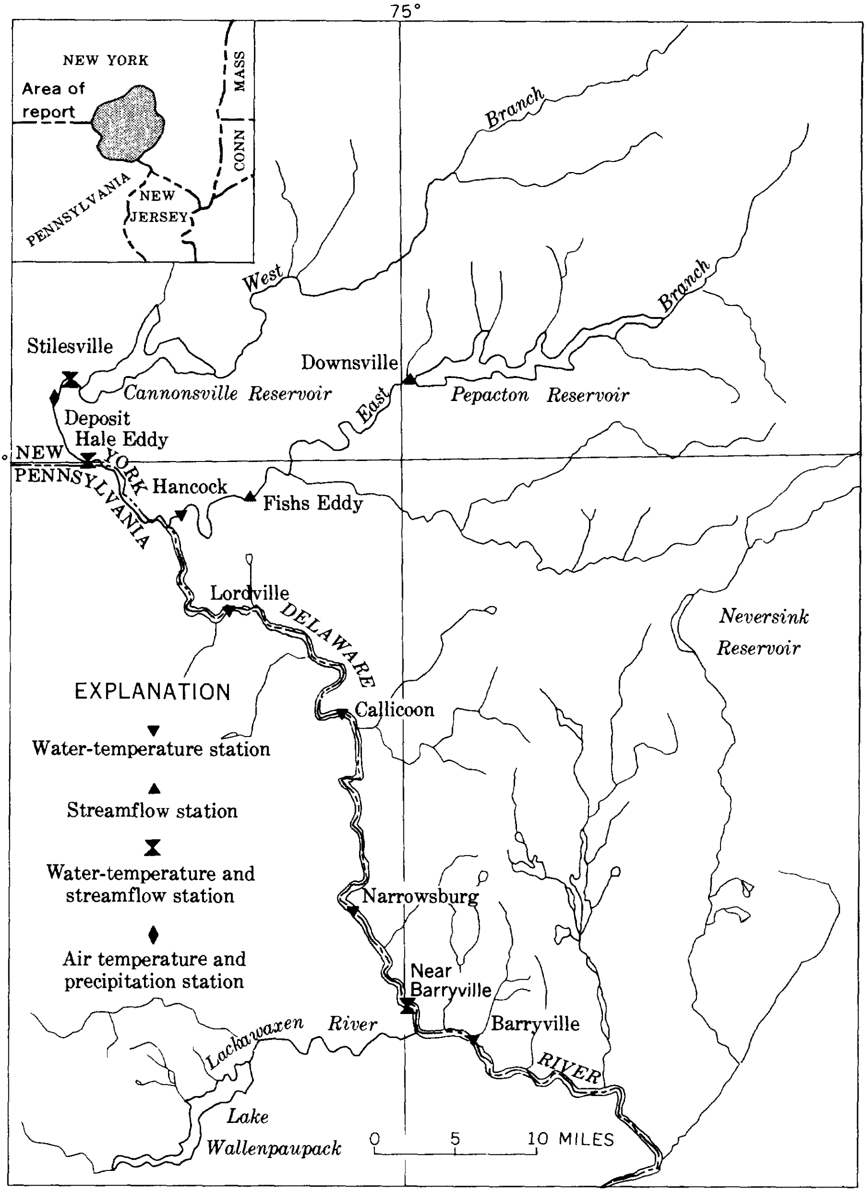

FIGURE 1.—Location of temperature-monitoring sites and streamflow-gaging stations.

miles along the main stem Delaware River from the confluence of the East and West Branches at Hancock to Barryville. The drainage area of the Delaware River at Barryville is 2,692 square miles. The drainage areas controlled by the Cannonsville and Pepacton Reservoirs are

454 and 371 square miles respectively. Pertinent information on mileages and drainage areas is presented in table 1.

Both Cannonsville and Pepacton Reservoirs are in the headwaters of the Delaware River, where the slopes of stream channels are steep. Each dam is more than 100 feet high, and water is released from a low-level outlet. The water in storage in both reservoirs spreads far beyond the former river channel into numerous fingers and embayments to provide a large surface area. Passage of water through the reservoirs may be discontinuous, and significant parts may remain in storage for nearly a year. Both reservoirs store substantial volumes of water during the winter and spring months and release substantial volumes during the summer and fall months, so as to maintain a minimal flow. Prior to completion of the Cannonsville Reservoir, a minimal flow of 1,525 cfs (cubic feet per second) in the Delaware River at Montague, N.J. (27.5 miles downstream from Barryville), was required. Upon completion of the Cannonsville Reservoir, the minimal flow to be maintained was increased to 1,750 cfs, subject to seasonal adjustment upward to 2,650 cfs, under a formula prescribed in a U.S. Supreme Court decree, amended in 1954.

Water-temperature data collected in the Pepacton Reservoir from 1959 to 1963, by the New York City Board of Water Supply, show that the reservoir becomes thermally stratified during the summer months. Because the Cannonsville Reservoir is a large storage reservoir in the same geographical area, there is little doubt it too becomes thermally stratified.

TABLE 1.—*Downstream distances from New York City reservoir sites and drainage areas*

Location	Distance, in miles— From Cannonsville Reservoir	Distance, in miles— From Pepacton Reservoir	Drainage area (sq mi)
Pepacton Reservoir		0	371
Cannonsville Reservoir	0	----------	454
Stilesville	1. 5	----------	456
Hale Eddy	8. 1	----------	593
Downsville		. 5	371
Fishs Eddy		21. 6	783
Hancock		31. 0	838
Confluence of two branches	17. 5	32. 6	1, 504
Lordville	26. 6	41. 7	1, 587
Callicoon	44. 3	59. 4	1, 706
Narrowsburg	55. 9	71. 0	1, 913
Near Barryville	66. 5	81. 6	2, 023
At Barryville	72. 0	87. 1	2, 692

COLLECTION OF DATA

Three types of installations have been used by various agencies to collect temperature data in the upper Delaware River basin.

At Stilesville (fig. 1) a thermograph attachment to the water-stage recorder inside a shelter has been used since 1962 to record stream temperature and water stage continuously on the same strip chart. The sensing element, a pressure-sensitive type, was in an intake pipe on the bottom of the river about 15–25 feet from shore during low water. These records are collected by the Geological Survey in its continuing cooperative program with the city of New York. Selected daily maximum and minimum temperatures from this record are listed in table 4.

The New York City Board of Water Supply installed similar thermograph recorders at Hale Eddy and near Barryville (fig. 1) during the summer of 1963. The sensing element, a thermocouple, is in a fashion similar to that at Stilesville. These recorders were installed inside Geological Survey shelters as units separate from the water-stage recorders. Variations in water temperature are recorded on a weekly circular chart. Data were obtained seasonally during August and September 1963 and during May through September 1964–67. These records also are summarized in table 4.

Waterproof thermograph recorders were installed as part of this project in the spring of 1964 at Hancock on the East Branch Delaware River and at Lordville, Callicoon, Narrowsburg, and Barryville on the main stem of the Delaware River (fig. 1). The waterproof thermograph recorder is contained in a stainless-steel case with an O-ring seal. These recorders were chained to two 100-pound blocks and placed on the streambed in flowing water from 3 to 6 feet deep. They were in operation for approximately 5 months, May through September 1964–67. The instruments were serviced once every 20–25 days. All stream-temperature data are verified by the manufacturers to be accurate within 1° (Celsius). Daily-maximum and daily-minimum stream temperatures at these stations are summarized in table 4.

In addition, streamflow records were obtained at continuous-recording gaging stations at Stilesville, Hale Eddy, Downsville, Fishs Eddy, and near Barryville (fig. 1). Also, maximum and minimum air-temperature records at two sites in the upper Delaware River basin, Deposit and Port Jervis (19.1 miles down stream from Barryville), were obtained from the U.S. Weather Bureau (1963–67).

ACKNOWLEDGMENTS

The author is grateful to Mr. Herbert A. Howlett, Jr., chief engineer, Delaware River Basin Commission, and to Messrs. Jess W. Malcolm, Kenneth Woodruff, and Warren Huff, formerly on the Delaware

River Basin Commission's staff, for their helpful advice, guidance, support, and assistance during this project. Acknowledgment is made also to Mr. Paul E. Blomquist, of the New York City Board of Water Supply, for his assistance in providing stream-temperature data at a number of sites.

The author also extends his appreciation and thanks to Robert E. Fish, deputy Delaware River master, Milford, Pa., Roy E. Campbell, U.S. Geological Survey, Middletown, N.Y., and James R. Slack, U.S. Geological Survey, Philadelphia, Pa., for their assistance. The report was prepared under the immediate supervision of Peter W. Anderson, Water Quality Section chief, and under the general supervision of John E. McCall, district chief, U.S. Geological Survey, Trenton, N.J.

ENVIRONMENTAL ANALYSES

Stream-temperature data collected in the upper Delaware River basin were analyzed to define: (1) Time and space variations and (2) the influence of climatologic conditions and reservoir releases upon stream temperatures. Statistical techniques used include frequency analyses, double-mass curve analyses, and simple graphical comparisons. Monthly statistics for each water-temperature monitoring site in the upper Delaware River basin are summarized in table 5.

VARIATIONS IN WATER TEMPERATURE

The relation between monthly mean temperature of the Delaware River at Narrowsburg, near Barryville, and at Barryville, and the monthly mean air temperatures at Deposit and Port Jervis (U.S. Weather Bureau, 1963–67) is depicted in figure 2 for the 1964–67 water years. Monthly mean stream temperatures for October through April during the period were estimated from records collected at Narrowsburg during 1948–51 (U.S. Geological Survey, 1954a, b, 1955). The plot shows that the monthly mean temperature of the Delaware River from Narrowsburg to Barryville is within 4°C of the monthly mean air temperature at Port Jervis, May through September 1964–67. Also, about 95 percent of the time, monthly mean stream temperatures at the three sites plot within 1°C of each other. The net difference in monthly mean stream temperature is ±1°C throughout the entire 16 mile reach. Indications are that stream temperatures relate more to climatologic conditions than to hydrologic conditions in this reach and that monthly mean air temperatures at Port Jervis are reasonable indices to the monthly mean stream temperatures from Narrowsburg to Barryville.

The use of seasonal air temperature as a reasonable index to seasonal water temperature was discussed for Pennsylvania streams by Mangan (1946, p. 9–10) and for Oregon by Moore (1967, p. 5–6). Mangan

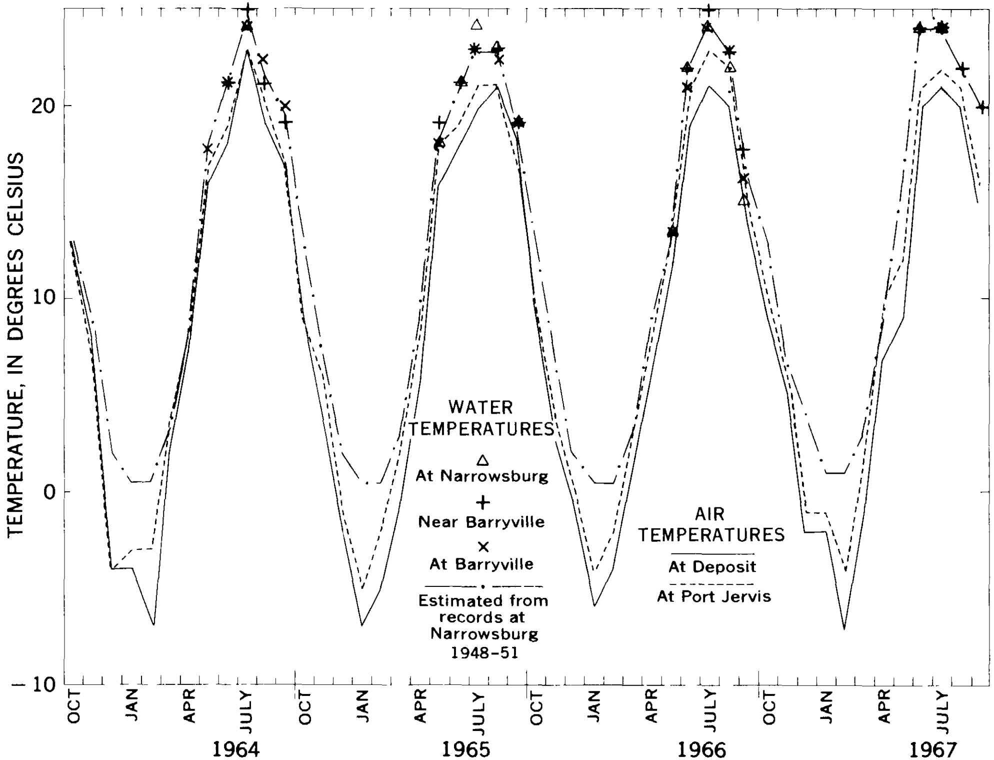

FIGURE 2.—Monthly mean water temperature in the upper Delaware River from Narrowsburg to Barryville and monthly mean air temperature at Deposit and Port Jervis, 1964–67 water years.

excepts streams that are affected by artifical impounding, and Moore also excepts streams that are either largely spring fed, north-south oriented, or shaded by wooded banks.

Data collected in the upper Delaware River between Narrowsburg and Barryville for this project indicate that long-term averages are not necessary for summer months, as the monthly mean water temperatures relate sufficiently well to monthly mean air temperature.

The Delaware River is basically north-south oriented. However, it is wide enough to avoid much shading by trees. Thus, water flowing in the reach from Narrowsburg to Barryville is exposed to direct sunlight during summer months. The river absorbs thermal energy at a slower rate than does the atmosphere, but also loses this energy at a much slower rate. This slower loss rate is apparently the reason that the monthly mean water temperatures tend to exceed the monthly mean air temperatures from March through November. During the winter months of December, January, and February, the lower thermal limit of 0°C also maintains the water temperature above the air temperature.

To define the seasonal variations of water temperature in the Delaware River from Narrowsburg to Barryville, the monthly mean water temperatures at three sites were averaged and a least-squares analysis made according to procedures described by Dixon and Massey (1957). These computations produced the following linear-regression equations:

Month	*Equations*
May	$y=16.43+1.11\ (x-16.00)$
June	$y=21.93+0.875\ (x-20.00)$
July	$y=24.02+0.545\ (x-22.25)$
August	$y=22.22+0.358\ (x-21.25)$
September	$y=18.70+1.27\ (x-16.25)$

where y is the estimated monthly mean water temperature at any site between Narrowsburg and Barryville and x is the monthly mean air temperature at Port Jervis. Using these equations, the monthly mean water temperatures of the Delware River between Narrowsburg and Barryville can be estimated from the monthly mean air temperatures. A plot of the observed monthly mean water temperatures and monthly mean air temperatures and the estimated regression line for each of the above equations is shown in figure 3.

To test the validity of these equations in describing the seasonal variations in stream temperature of the Delaware River between Narrowsburg and Barryville, mean monthly air temperatures at Port Jervis were computed for May to September by averaging 5 years (1963–67) of air-temperature data (U.S. Weather Bureau, 1963–67). These average air temperatures were assumed to be the normal for each month and were used to estimate the corresponding mean monthly

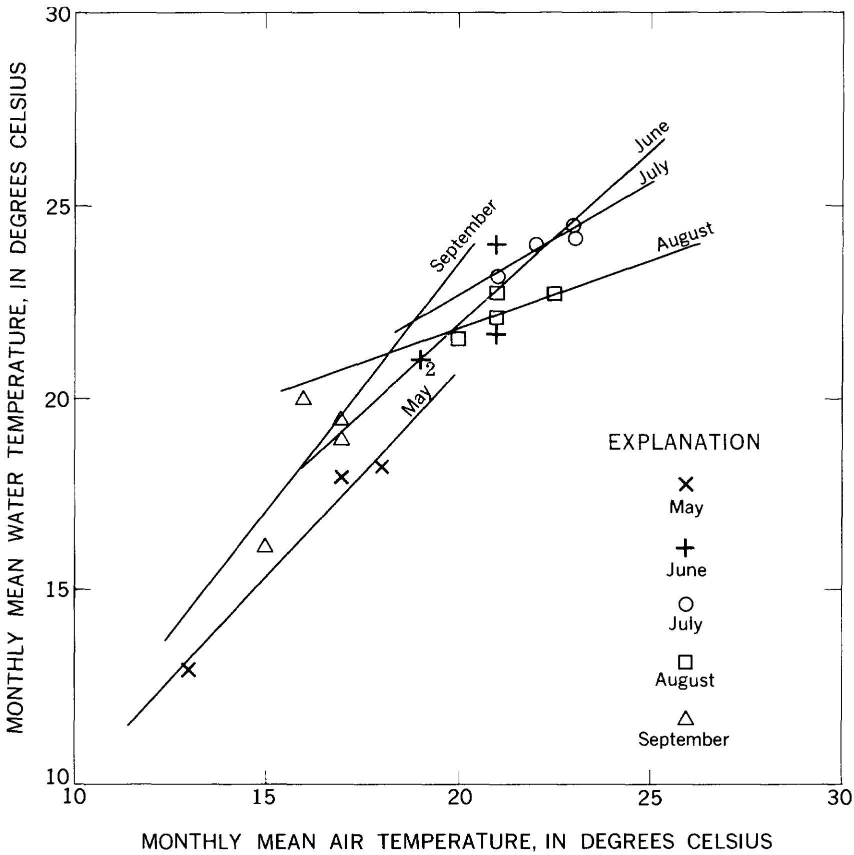

FIGURE 3.—Relation of monthly mean water and air temperatures from Narrowsburg to Barryville, May–September 1964–67. described by linear-regression analysis.

water temperatures for May through September from the equations on p. K8. The computed and observed mean monthly water temperatures were the same for each month: 16°C for May, 22°C for June, 24°C for July, 22°C for August, and 19°C for September.

Upstream from Narrowsburg, temperatures of the main stem of the Delaware River do not relate as well to air temperatures as temperatures at downstream sites; stream temperatures depart from air temperature even more in the East Branch and West Branch Delaware River. Figure 4 depicts the monthly mean water temperatures on the main stem above Narrowsburg and on the East and West Branches and depicts monthly mean air temperatures at Deposit for the periods May–September 1964–67. This plot shows that water temperatures generally increase in a downstream direction and that the monthly

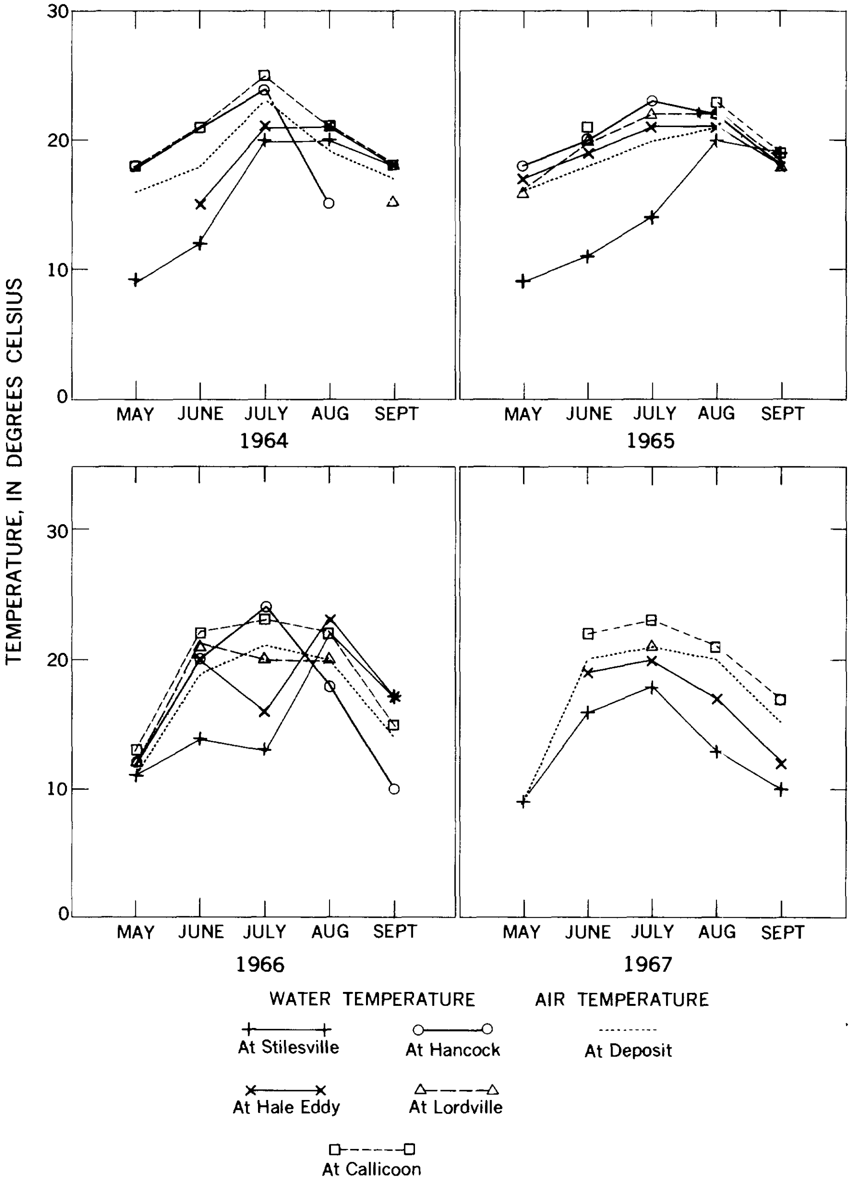

FIGURE 4.—Monthly mean water temperatures on the main stem Delaware River at Callicoon and Lordville, on East Branch Delaware River at Hancock, and on West Branch Delaware River at Hale Eddy and Stilesville, and monthly mean air temperatures at Deposit, May–September 1964–67.

mean water temperatures at Lordville and Callicoon were consistently higher than either those on the East Branch or those on the West Branch and, at times, higher than both.

The illustration shows that monthly mean water temperatures deviate increasingly from monthly mean air temperatures in an upstream direction. This deviation indicates that in the East and West Branches of the Delaware River a factor or factors other than climatologic conditions are affecting water temperature.

The influence of this factor is great enough to maintain lower stream temperatures than might be expected from local climatologic conditions. For example, the monthly mean water temperatures (fig. 4) at Stilesville, Hale Eddy, and Lordville are lower for July 1966 than for June 1966, whereas the monthly mean air temperature is higher.

INFLUENCE OF RESERVOIR DISCHARGES

MONTHLY WATER TEMPERATURES

Monthly mean water temperatures on the West Branch Delaware River at Stilesville, prior to initiation of storage at and releases from Cannonsville Reservoir, and monthly mean air temperatures at Deposit and Port Jervis for May–September 1963 are depicted in figure 5. This illustration shows that the monthly mean water temperature at Stilesville generally related to the monthly mean air temperature at Deposit. However, figure 4 shows deviations in this relation for later data collected at this site.

A comparison of monthly mean air and water temperatures with monthly mean streamflow at Stilesville for the periods May–September 1963–67 (fig. 6) suggests that this lack of relation between air and water temperatures probably results from reservoir releases. The monthly mean streamflows at Stilesville prior to 1964 can be considered natural flow; streamflow subsequent to 1964 is a combination of releases and overflow from Cannonsville Reservoir. The mean streamflow at Stilesville for May 1963 was 566 cfs and the mean water temperature was 14°C (table 5). Monthly mean water temperatures for May 1964–67 range between 9° and 11°C. This suggests that the temperature of the water released from the reservoir was colder during 1964–67 than the natural flow in May 1963. Monthly mean water temperatures for June and July during 1964–67 are also lower than those observed in June and July 1963 at Stilesville.

The effect of water released through the reservoir's low-level outlet is most noticeable in the plot for June and July 1966 in figure 6. Releases from Cannonsville Reservoir in July were much greater than those in June; water temperatures in July were lower than in June, although this occurred at a time when natural downstream temperatures would be expected to be increasing. This suggests that the large volume of water released in July influenced downstream temperatures to a greater extent than did the small volume released in June.

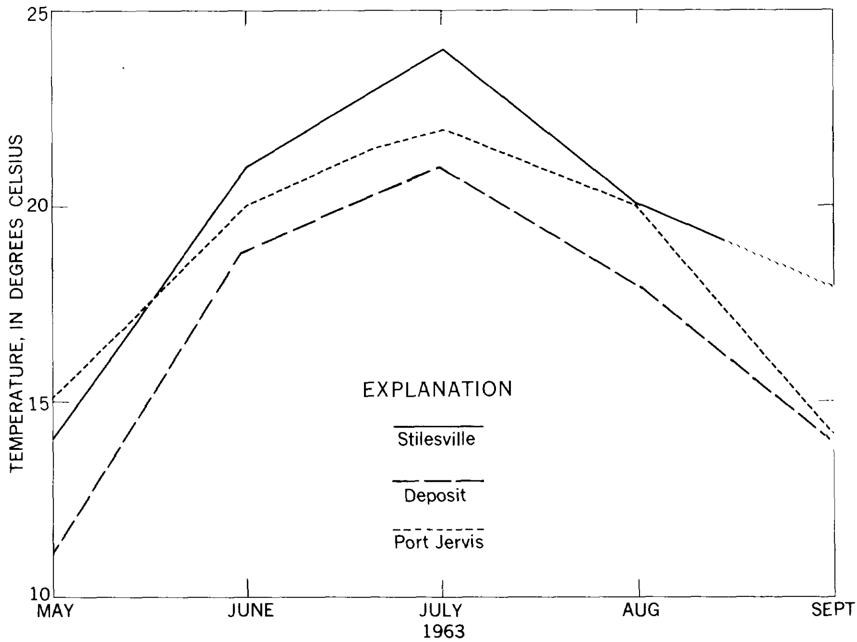

FIGURE 5.—Monthly mean temperature of the West Branch Delaware River at Stilesville and monthly mean air temperature at Deposit and Port Jervis, May–September 1963.

The relation between monthly mean air and water temperatures for August and September 1964–66 (fig. 6) approximates that for August and September 1963, but the August and September 1967 curves do not. A possible explanation is that releases through the low-level outlet from May to July in the 1964–66 period, at a time when the reservoir always stored less than 50 percent of its total capacity, effectively depleted the hypolimnion—the cold water in the bottom of the reservoir. Thus, by late summer in 1964–66, warmer water was being released. In 1967, however, the reservoir was filled to capacity and low-level releases were entirely from the hypolimnion through the summer and early fall.

A similar comparison of streamflow on the East Branch Delaware River at Downsville with water temperatures at Hancock and air temperatures at Deposit (fig. 7) indicated that the effect of releases from the Pepacton Reservoir on downstream water temperatures in the East Branch Delaware River is dependent upon the release rate. Streamflow data at Downsville, 0.5 mile below the reservoir, was used to indicate the reservoir-release rate. When releases from this reservoir were relatively small, as during May–September 1965, monthly mean water temperatures at Hancock (31 miles below the reservoir) were

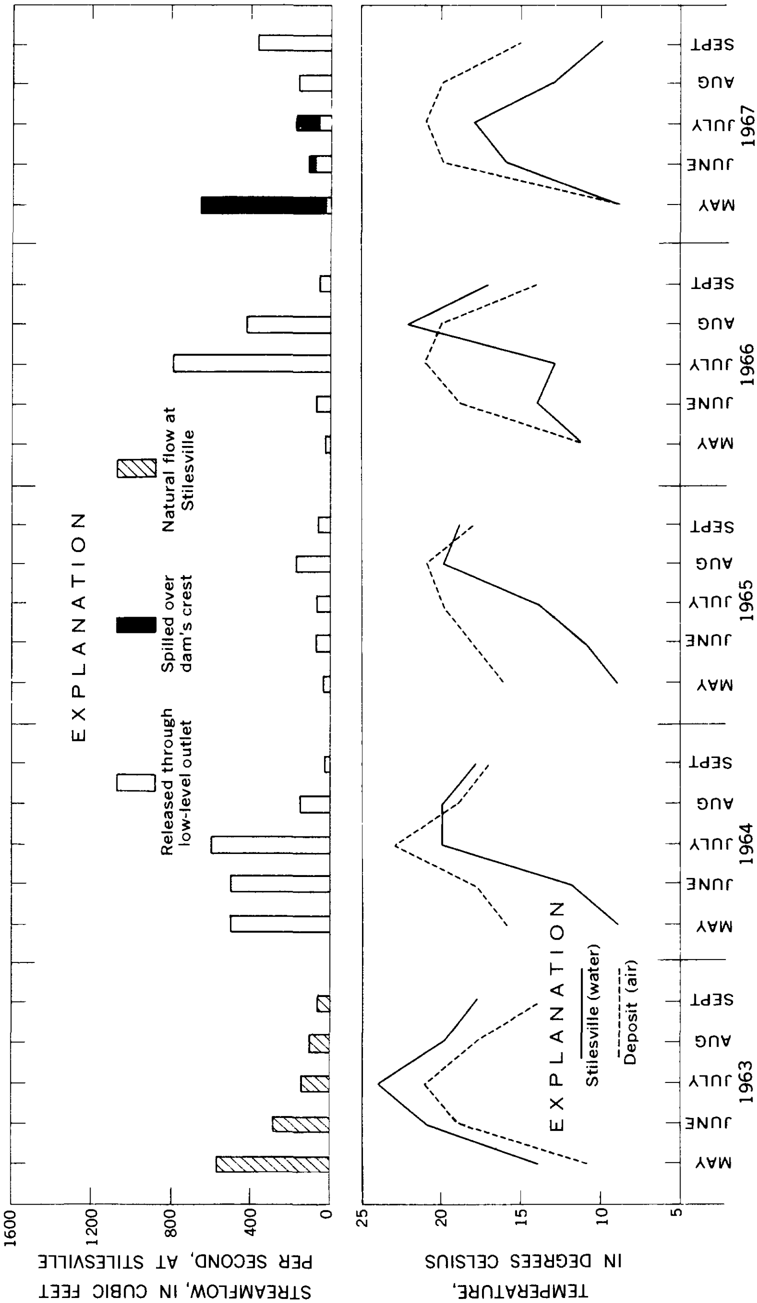

FIGURE 6.—Monthly mean water temperature, air temperature, and streamflow in the West Branch Delaware River, May–September, 1963–67.

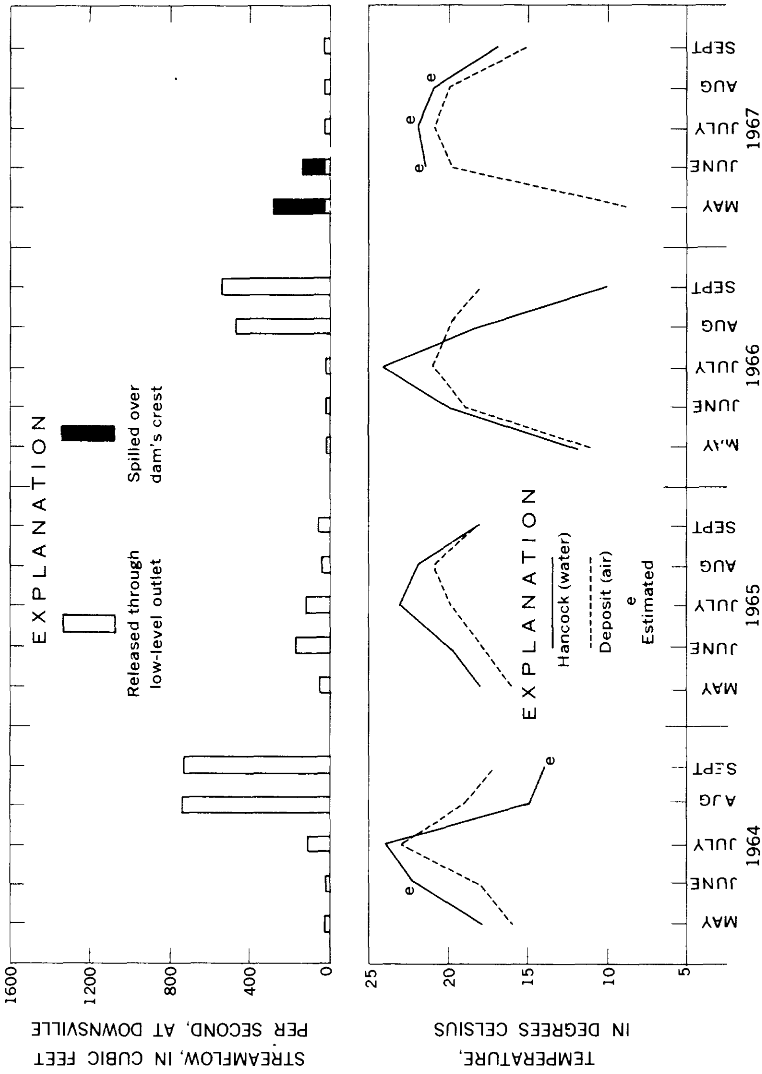

FIGURE 7.—Monthly mean water temperature, air temperature, and streamflow in the East Branch Delaware River, May–September 1964–67.

as much as 3°C warmer than those of the air. When releases were relatively large, as in the period August and September 1964 and 1966, water temperatures were as much as 4°C colder than the corresponding air temperatures. Apparently the larger the release rate through Pepacton's low-level outlet, the longer it takes for climatologic conditions and the natural inflow of tributaries to warm the release water. This same relationship was observed at other sampling sites as far downstream as Callicoon, 59 miles below the reservoir.

It is possible to estimate the effect of releases from Cannonsville Reservoir on water temperatures at Stilesville by assuming that the 1963 relation (fig. 5) and the slope of the regression curves (fig. 4) both approximate the relationship between air and water temperature at this site prior to reservoir storage. By plotting the monthly mean water temperatures at Stilesville against the monthly mean air temperatures at Deposit for the period May–September 1963 and then drawing lines through each point based on the assumed slopes, the relation between these parameters can be estimated (fig. 8). Therefore, natural monthly mean water temperatures can be estimated, based on observed air-temperature data. The difference between the estimated monthly mean water temperatures and the observed temperatures (table 5) is the estimated influence at Stilesville of releases from Cannonsville Reservoir. These estimates are summaried in table 2. Similar estimates were made for the effect of releases from the reservoir on water temperature at Hale Eddy, the effect at Hancock of releases from the Pepacton Reservoir, and the effect at Lordville and Callicoon of releases from both reservoirs (table 2). These estimates were made with

TABLE 2.—*Estimated effect of summer reservoir releases on downstream water temperature (° C) at selected sites in the upper Delaware River basin*

Site	1964					1965				
	M	J	J	A	S	M	J	J	A	S
Stilesville	−10	−8	−5	0	−1	−10	−9	−9	−1	−2
Hale Eddy	—	−6	−5	0	−1	−3	−2	−3	−1	−3
Hancock	−1		−2	−6		−1	−1	−1	0	−4
Lordville					−6	−2	−1	−2	0	−4
Callicoon	−2	0	−1	−1	−1		0		0	−2

Site	1966					1967				
	M	J	J	A	S	M	J	J	A	S
Stilesville	−3	−7	−9	0	+1	−3	−6	−6	−8	−7
Hale Eddy		−2	−9	+1	0		−4	−5	−5	−6
Hancock	−3	−2	−1	−4	−7					−1
Lordville	−3	−1	−5	−2				−4		
Callicoon	−2	0	−2	0	−2		−1	−2	−1	−1

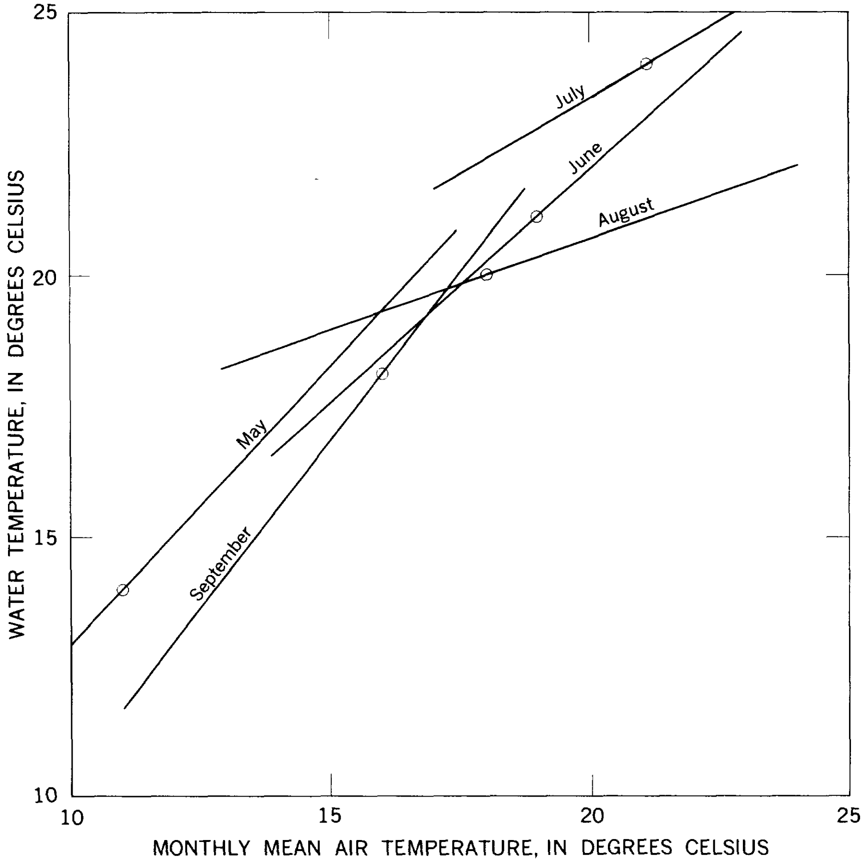

FIGURE 8.—Estimated relation of monthly mean stream and air temperatures at Stilesville, May–September 1964–67, assuming no reservoir effect.

the assumption that natural monthly mean water temperatures for all downstream sampling sites would be 1°C warmer than that of the observed 1963 water temperatures at Stilesville, based upon previously noted observations of monthly mean water temperature between Narrowsburg and Barryville.

Analyses of monthly air and water temperatures, streamflows, and depth of reservoir storage indicate that the influence of the Cannonsville and Pepacton Reservoir releases on downstream water temperature is largely dependent upon five factors:

1. Presence of thermal stratification in the reservoir.
2. Depth at which water is released from the reservoir, that is, whether by low-level outlet or by spilling over the reservoir's crest.
3. Rate of release from the reservoir.

4. Distance downstream from the reservoir.
5. Concurrent climatologic conditions.

Monthly mean ranges of water temperatures from May through September 1963–67 are reported in table 5. Ranges at Stilesville were as low as 1°C in July 1966 and as high as 7°C for June 1966; those at Hale Eddy were as low as 4°C in August 1966 and as high as 8°C for May 1965. Monthly mean ranges at Hancock on the West Branch Delaware River and at the other sites on the main stem are mostly between 2° and 3°C.

Figure 9 shows that the monthly mean ranges in air temperature at Deposit were more than twice that of monthly mean ranges in water temperature at Stilesville during the period May–September 1963–67. During 1963, the monthly mean minimum water temperatures at Stilesville were always higher than the corresponding mean minimum air temperatures, whereas during 1964–67, the mean minimum water temperatures were at times less than the mean minimum air temperatures.

Figure 9 also shows that large releases of water, presumably from the hypolimnion, decreased both the maximum and minimum observed water temperatures and, thus, shortened the range of temperature. Small releases decreased the monthly minimum, probably had less effect on maximums, and, thus, increased the range. Note that releases of warmer water, as in August and September 1964–66, tended to approximate the natural relation observed between the air and water temperature ranges in 1963. By comparing data for May 1963 with those for 1967, one observes that large spills over the dam in 1967 appeared to have lowered both maximum and minimum water temperatures in relation to corresponding air temperatures and to have greatly contracted the range.

A similar comparison of the monthly mean ranges in water temperature at Hale Eddy with those of air temperature at Deposit (fig. 10) suggests that the rate of release from the reservoir (fig. 9) does not affect ranges at Hale Eddy as much as those at Stilesville. The ranges shortened to 4°C in August and September 1966, apparently as a result of large releases of warmer water.

Monthly mean ranges at Hancock on the East Branch Delaware River and at the other sites on the main stem are at most only slightly affected by Pepacton Reservoir releases.

DAILY WATER TEMPERATURES

The varied effects of releases from the low-level outlet and water spilling over the Cannonsville Dam on the water temperatures at Stilesville, Hale Eddy, and Callicoon from May to September 30, 1967, are illustrated in figure 11. During the entire period, water was released

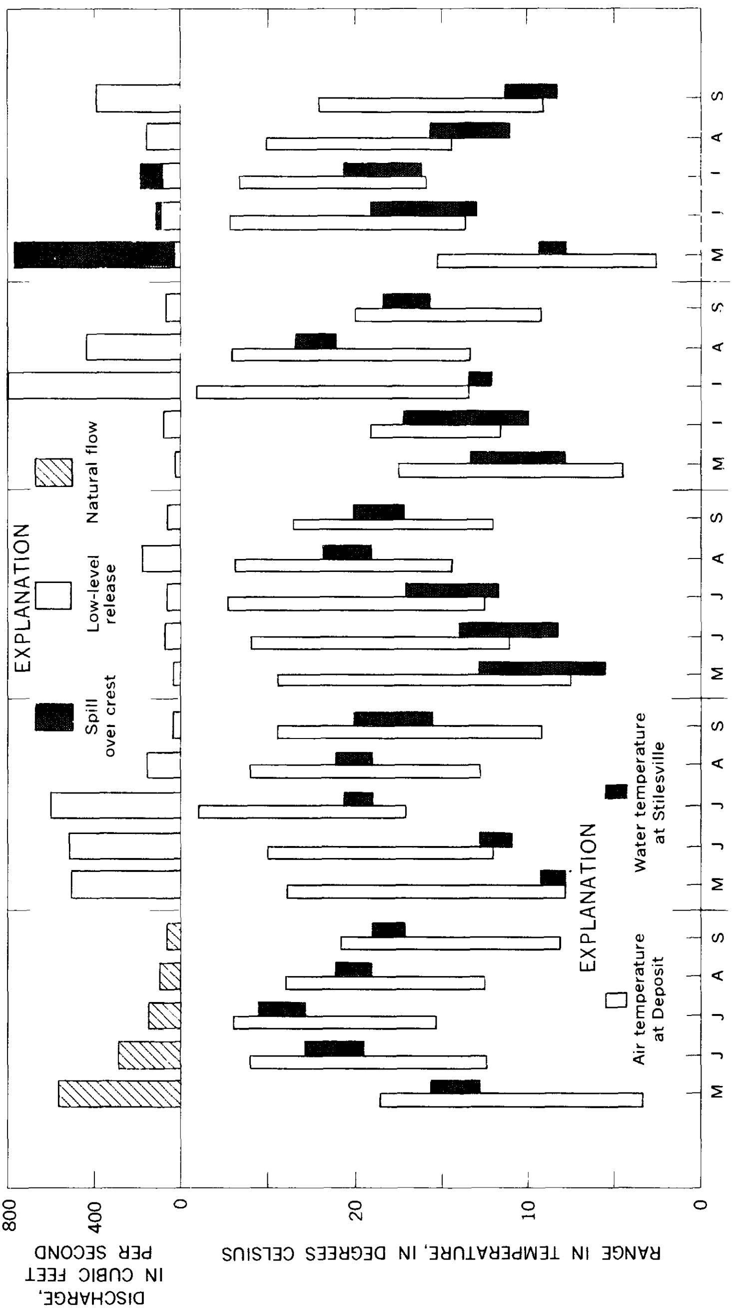

FIGURE 9.—Monthly mean discharge and monthly mean ranges of water temperature at Stilesville and of air temperature at Deposit, May–September 1963–67.

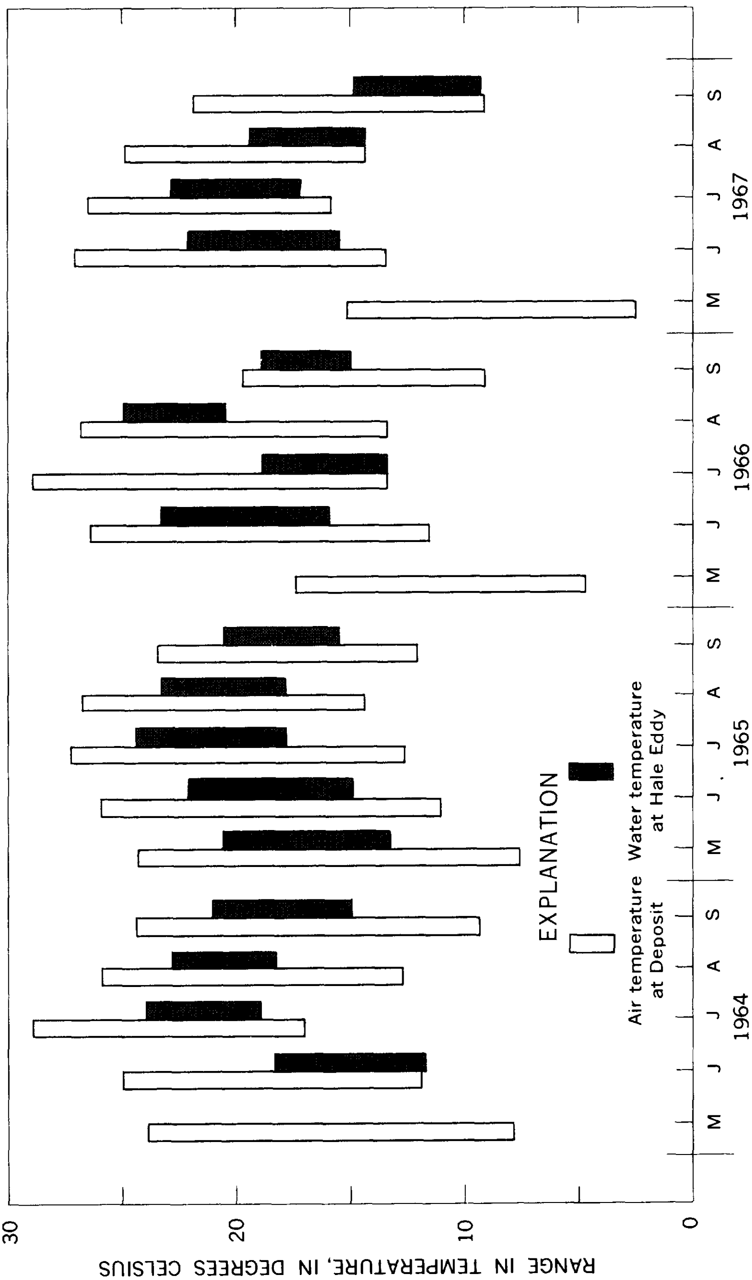

FIGURE 10.—Monthly mean ranges of water temperature at Hale Eddy and of air temperature at Deposit, May–September 1964–67.

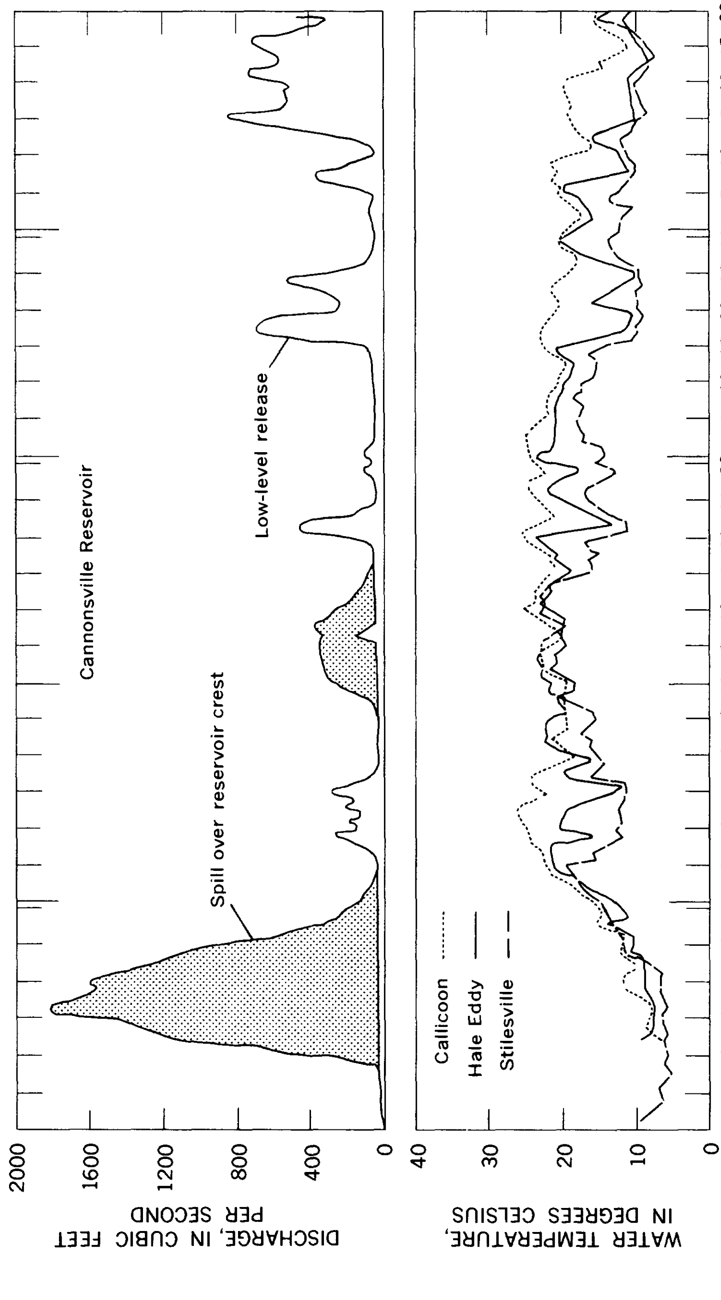

FIGURE 11.—Daily mean water temperature and discharge in the upper Delaware River basin, May–September 1967.

through the low-level outlet; water spilled over the dam from May 10 to June 5 and from June 27 to July 14. No temperature data were obtained at Hale Eddy prior to May 12. From May 12 to September 30, excepting three periods (May 12–23, June 4–5, and September 22–26), the river water was colder at Stilesville than at Hale Eddy when water did not spill over the dam, and warmer at Stilesville than at Hale Eddy when water did spill over the dam. This suggests that the reservoir was stratified during most of the period. In addition, the effects observed during May 12–23 and September 22–26 suggest the insignificance of thermal stratification in relation to climatologic conditions during May and late September. On June 4 and 5, the volume of water released through the low-level outlet approximated the volume that spilled over the dam. Thus, because of mixing, the water that spilled over the dam did not influence downstream temperature as expected.

The effect of water spilling over the dam on water temperature at Stilesville was quite evident. For example, water temperatures at Stilesville increased 7°C during the period June 26 to July 2 as spill over the dam increased from 0 to 320 cfs and then decreased 7°C as spill over the dam decreased back to zero by July 15. The daily mean water temperatures at Stilesville were consistently higher when there was spill over the dam and lower when water was released only through the low-level outlet.

Spilling apparently had little or no effect on water temperatures at Hale Eddy and Callicoon. In contrast, temperatures decreased markedly as far downstream as Callicoon, when the flow past Stilesville was augmented by releases through the low-level outlet. For example, when the flow past Stilesville was increased from 29 cfs on August 14 to 679 cfs on August 18 (fig. 11), water temperature decreased 8°C at Stilesville, 10°C at Hale Eddy, and 3°C at Callicoon.

Data collected from May to September 1964–66 show that releases through the low-level outlet from Cannonsville and Pepacton Reservoirs sometimes were accompanied by decreases in water temperatures as far downstream as Narrowsburg. In 1966, releases through the low-level outlet at Cannonsville Reservoir lowered water temperatures by 13°C (Williams, 1968, incorrectly reported 26°F) at Hale Eddy, 4°C at Callicoon, and 1°C at Narrowsburg (Williams, 1968). Releases through the low-level outlet at Pepacton Reservoir lowered water temperatures by 11°C at Hancock, 3°C at Callicoon, and 1°–3°C at Narrowsburg.

To confirm that a change in the proportionality between climatologic conditions and water temperature had occurred at the time reservoir releases began, double-mass curves were constructed. A double-mass curve for June 19–30, 1966, is given in figure 12 as an example. The

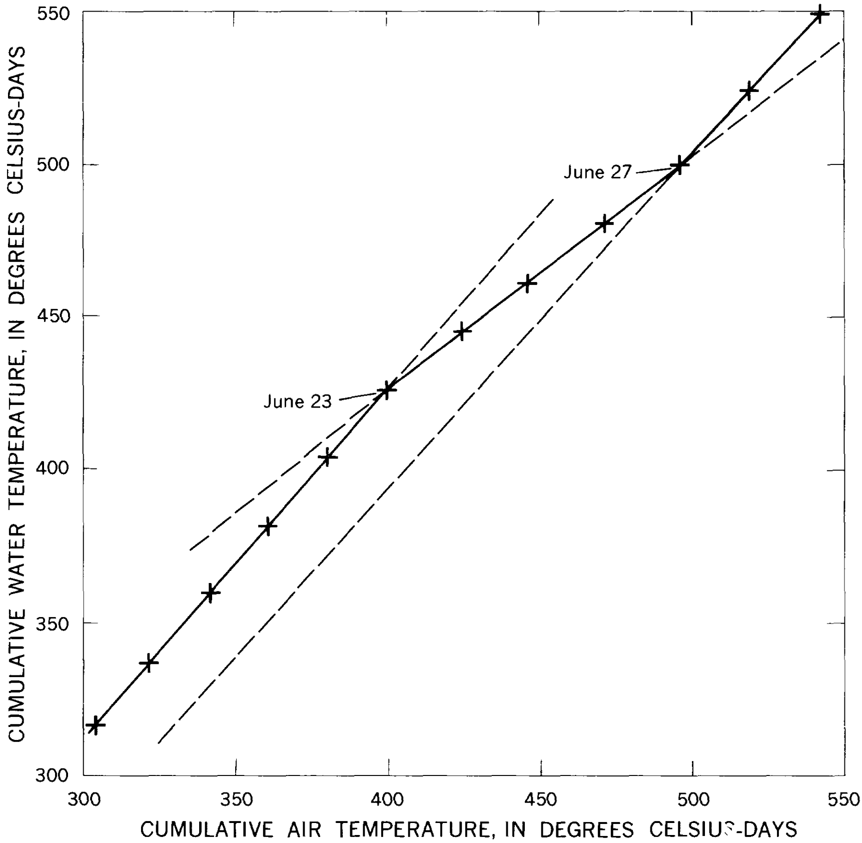

FIGURE 12.—Double-mass curve—cumulative air temperature at Deposit versus cumulative water temperature at Hale Eddy, June 19–30, 1966.

cumulative air-temperature values at Deposit were plotted against the cumulative water-temperature values at Hale Eddy. Streamflow at Stilesville increased from 23 cfs on June 22 to 420 cfs on June 24, 1966, then decreased on June 25. Although air temperatures at Deposit increased 4°C, water temperatures at Hale Eddy, 8.1 miles downstream from the dam, decreased 7°C. When releases were cut back on June 25, water temperatures at Hale Eddy rose 12°C whereas air temperatures decreased about 2°C. The change in slope on June 23 indicates a change in proportionality between climatologic conditions and water temperatures. This suggests that the rate of increase of water temperature was inversely proportional to the rate of increase of air temperature. As water releases were reduced (June 27), the slope approximated that defined prior to the start of releases. Dashed lines, representing extension of defined linear relations, have been added to this illustration to facilitate its interpretation.

To examine the diurnal fluctuation in temperature, plots were prepared of hourly water temperatures at Hale Eddy, Hancock, and Callicoon and compared with air temperatures at Deposit. The combined plot of water and air temperatures for June 20–26, 1966, is shown in figure 13. The temperatures plot as sinusoidal curves, with the curve for Hale Eddy having the largest amplitude of the three water-temperature curves. The maximum daily water temperature occurred between 4:00 p.m. and 6:00 p.m., within an hour of maximum air temperature. The minimum water temperatures generally occurred between 6:00 a.m. and 9:00 a.m., about 2–3 hours after the minimum air temperature.

Releases from Cannonsville Reservoir were steady at 23 cfs until 3:00 p.m. on June 23; the release rate then increased to 400 cfs by 3:00 p.m. on June 25. The axis of the curve for Hale Eddy dropped about 7°C on June 24 with a slight decrease in the range of diurnal fluctuations. This was in response to increased volumes of cold water at the same time that air temperatures rose slightly. The large diurnal fluctuation is probably related to the close proximity of Hale Eddy to Cannonsville Reservoir. Water released from the reservoir during the morning receives maximum solar radiation while in transit to Hale Eddy, whereas water released during the evening receives little or no solar radiation. Before reaching Callicoon, water from the reservoirs was affected by both day and night conditions, accounting for the lower daily minimum water temperatures. The larger volume of water in the East Branch Delaware River above Hancock (384–578 cfs) reacts less to diurnal temperature variations.

The effects on water temperature of increased releases on June 23 were observed at Callicoon on June 25. Water temperatures at Callicoon were usually about 3°C above those at Hancock on the East Branch Delaware River prior to the morning of June 25. Temperatures at Callicoon stabilized on June 25, whereas temperatures at Hancock, which were unaffected by releases from Cannonsville Reservoir, increased to within 1°C of those at Callicoon by late in the evening. Although there was no decrease noted in water temperature at Callicoon, there was a change in its rate of increase. This change indicated that the effects of releases from Cannonsville Reservoir were shadowed by climatological conditions.

The preceding discussion indicates that water temperatures in the West Branch Delaware River between Cannonsville Reservoir and the confluence with the East Branch are dependent upon the temperature of the water released from the reservoir, the rate of release, the

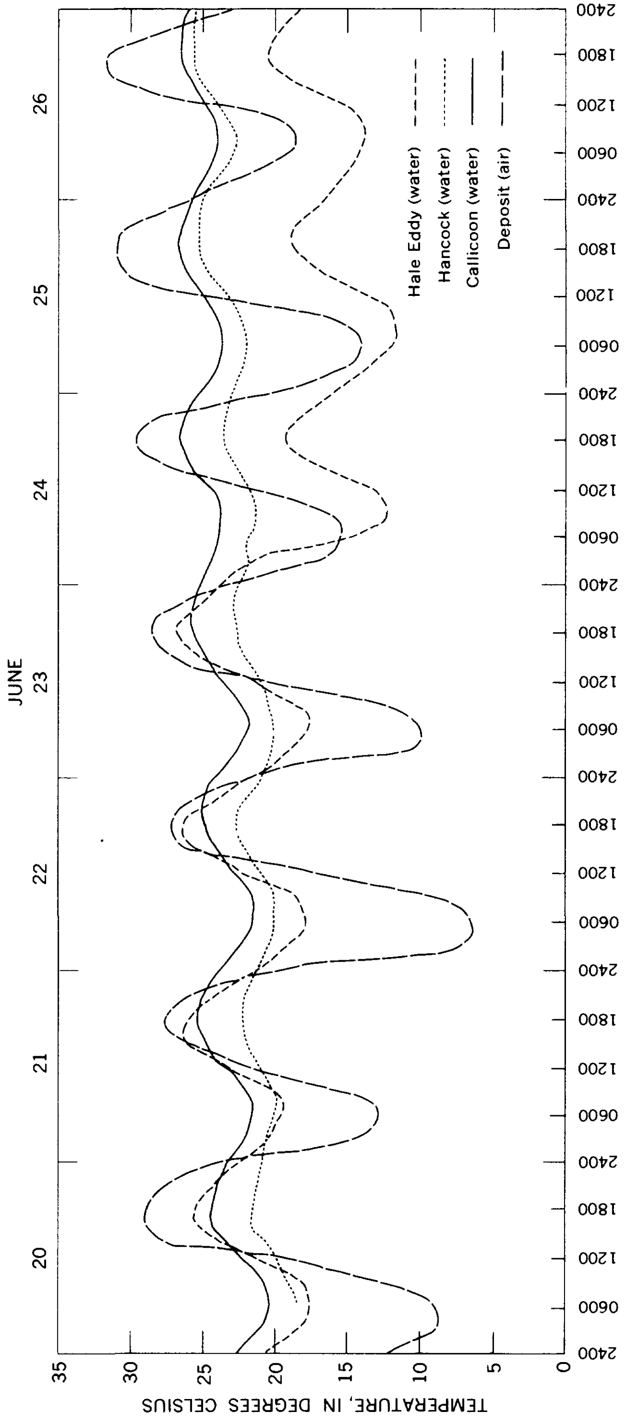

FIGURE 13.—Hourly air and water temperatures in the upper Delaware River basin, June 20–26, 1966.

downstream distance from the reservoir of the site at which water temperature observations are being recorded, and variations in climatologic conditions during the period of observation.

Similar analyses of daily water temperatures in the East Branch produced similar conclusions concerning the influence of releases from the Pepacton Reservoir upon temperature observations at downstream sampling sites. The estimated traveltime for the effect of increased releases from this reservoir on water temperatures at Hancock, based on observations made during August 1964 and 1966 was about 1.5 days. Similarly, the effects of these releases were observed at Callicoon in about 2 days.

Increased release rates from the Cannonsville Reservoir were observed to have a greater effect on daily maximum water temperatures at Stilesville than on daily minimum water temperatures (fig. 14). The release rate during June was about 25 cfs except on June 10, when the rate was 37 cfs and on June 23–30, when the rate ranged between

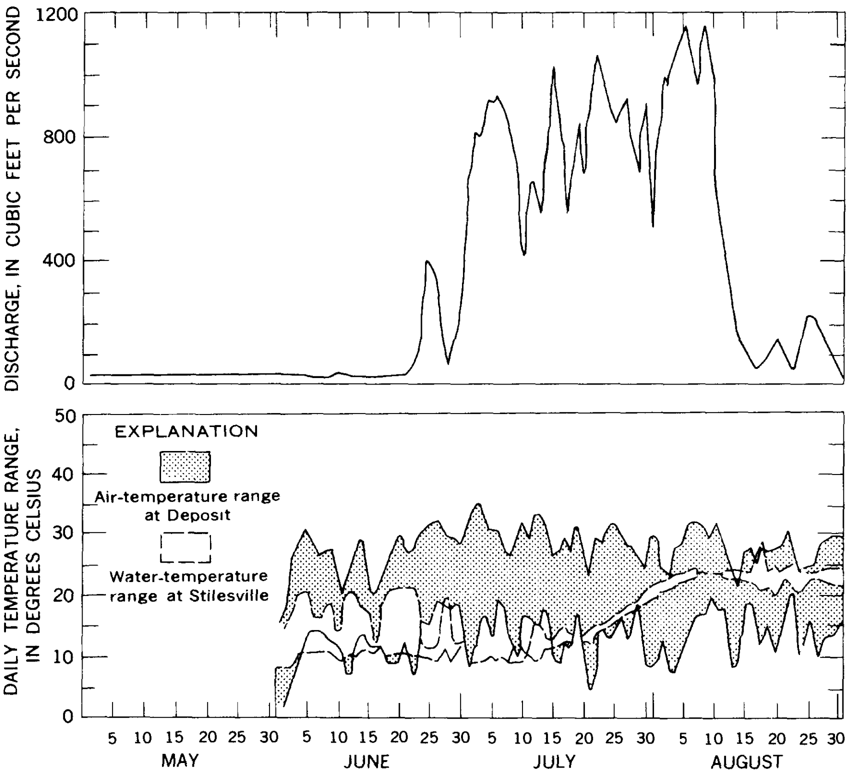

FIGURE 14.—Water-temperature range and discharge at Stilesville and air-temperature range at Deposit, June–August 1966.

51 and 420 cfs. Minimum water temperatures during June ranged between 8° and 11°C, whereas maximum water temperatures ranged between 11° and 21°C. Maximum and minimum water temperatures related well to maximum and minimum air temperatures until June 23, when release rates were increased greatly. Subsequent to this date and throughout July and early August daily maximum water temperatures responded to the variations in the release rate. However, during this period, daily minimum water temperatures showed little or no response to corresponding air temperature variations or to reservoir-release rates. After August 15, when release rates were reduced to about 140 cfs, the response to variations in air temperature were again observed. The higher release rate diminished the effect of climatologic conditions on the water temperature.

Analyses of daily minimum water temperatures observed in 1964 at Stilesville suggest that water released after the end of June was from the thermocline and epilimnion. In 1965, data suggest that releases after mid-July were from the thermocline and, by August, from the epilimnion. Water released through the low-level outlet during 1967 was probably entirely from the hypolimnion.

The influence of releases from Cannonsville Reservoir on daily maximum and minimum water temperatures at Hale Eddy was dependent upon the magnitude of the releases. For example, when releases increased from 23 to 420 cfs during June 23–25, 1966, the daily maximum water temperature decreased 10°C at Stilesville and 8°C at Hale Eddy, and the daily minimum water temperature, which was not affected at Stilesville, dropped 6C at Hale Eddy. When releases increased from 51 to 915 cfs between June 28 and July 4, the effect on both maximum and minimum water temperatures was greater at Hale Eddy than it was at Stilesville, these releases decreased both the maxinum and minimum water temperatures 13°C at Hale Eddy. The maximum water temperatures at Stilesville decreased 12°C, whereas the minimum water temperatures decreased only 3°C.

The influence of large releases on the daily minimum water temperatures was more apparent at Hale Eddy than at Stilesville. Previous small releases had lowered the daily minimum at Stilesville near to the temperature of the water released. Therefore, a large release did not lower the daily minimum as much at Stilesville as it did at Hale Eddy.

Further analyses of the data indicated releases from Cannonsville Reservoir decreased the daily maximum water temperatures more than the daily minimum temperatures in the West Branch Delaware River as far downstream as Hale Eddy. The effect upon the daily maximum water temperatures in the mainstem Delaware River was only slightly greater than that on daily minimums. Releases from Pepacton

Reservoir similarly lowered daily maximum water temperatures on the East Branch Delaware River at Hancock by about 1°C more than daily minimums and were only slightly more effective on daily maximum water temperatures than daily minimums as far downstream as Callicoon.

FREQUENCY ANALYSES

Frequency analyses (table 3) were performed on hourly water-temperature data at each site for the months of June, July, and August. A comparison of monthly temperature frequencies at a site can be used to indicate which period is most thermally suitable for various species of aquatic life at that site. Also, a comparison of monthly stream-temperature frequencies at one site with those at other sites can be used to indicate which site is most thermally suitable. For example, if the range of thermal tolerance of a particular species is between 16°C and 29°C, then the frequencies reported in table 3 indicate that July is the most thermally suitable month at Hancock, that Stilesville and Hale Eddy are not suitable, and that the most suitable sites are downstream from Callicoon.

CONCLUSIONS

The objectives of this cooperative investigation were to (1) define the variations in water temperature during the summer months, (2) determine the effect of reservoir releases on downstream water temperatures, and (3) provide data from which the thermal suitability of the study area as a spawning and nursery habitat for anadromous fish can be determined.

The effect of climatologic conditions on stream temperatures in the upper Delaware River basin is to increase the water temperatures from February through July and to decrease temperatures from August through January. Water temperatures of the Delaware River between Narrowsburg and Barryville normally relate well to air temperature at Port Jervis. On the East and West Branches and on the main stem Delaware River, as far downstream as Callicoon, the predominant controlling influence on stream temperature seemed to be reservoir releases. This influence decreased with distant downstream, but was a major factor as far downstream as Callicoon. The influence that releases from Cannonsville and Pepacton Reservoirs have on downstream water temperatures was dependent upon five factors:

1. Thermal stratification in the reservoir.
2. Depth at which water was released.
3. Rate of release.

4. Distance downstream from the dams.
5. Climatologic conditions.

The effect of relatively large releases from both reservoirs on daily mean water temperature was observed as far downstream as Narrowsburg, 71.0 miles below Pepacton Reservoir and 55.9 miles below Cannonsville Reservoir. Releases from Cannonsville Reservoir were observed to decrease daily mean water temperature by 13°C on the West Branch at Hale Eddy, 8.1 miles downstream, and by about 1°C on the Delaware River at Narrowsburg, 55.9 miles downstream. Releases from Pepacton Reservoir have been observed to decrease daily mean water temperature by 11°C on the East Branch Delaware River at Hancock, 31.0 miles downstream, and between 1°–3°C at Narrowsburg, 71.0 miles downstream.

When Cannonsville Reservoir had less than 50 percent of its total capacity, as during most of the study period, 1964–66, releases through the low-level outlet from May through July were thought to have drained the hypolimnion. Thus, warmer water from the upper strata or epilimnion was released during August–September. Water spilling over the reservoir's crest, beginning in 1967, was observed to have similar effects on downstream water temperatures as low-level releases from the epilimnion.

Releases from Cannonsville Reservoir decreased the daily-maximum water temperatures more than the daily-minimum temperatures in the West Branch Delaware River as far downstream as Hale Eddy. The effect upon the daily maximum water temperatures in the main stem Delaware River was only slightly greater than that on daily minimums. Releases from Pepacton Reservoir similarly lowered daily maximum water temperatures on the East Branch Delaware River at Hancock by about 1°C more than daily minimums and was only slightly more effective on daily maximum water temperatures than daily minimums as far downstream as Callicoon.

Relatively large monthly releases from Cannonsville Reservoir decreased the monthly mean range to as little as 1°C on the West Branch Delaware River at Stilesville. In contrast, relatively small releases (less than 25 cfs) produced a monthly mean range of about 7°C. Monthly mean water temperature ranged between 4° and 8°C in the West Branch Delaware River at Hale Eddy. In the East Branch Delaware River at Hancock and at other sites on the main stem, monthly mean temperatures ranged mostly between 2° and 3°C. Little or no effect from releases upon the monthly mean range was observed at these latter sampling sites.

TABLE 3.—*Summary of frequency analyses of water temperature, in degrees Celsius, in the upper Delaware River basin, 1964–67*

Station	Station name	Period	Percentage of time the temperature equaled or exceeded the estimate											
			1	2	5	10	20	50	80	90	95	98	99	99.99
1–4215.00	East Branch Delaware River at Hancock, N.Y.	June 1965–66	27	27	26	25	24	21	17	15	14	13	12	11
		July 1964–66	28	28	28	27	26	24	22	21	20	19	18	16
		Aug. 1964–66	28	27	27	25	24	18	15	14	14	13	13	12
1–4250.00	West Branch Delaware River at Stilesville, N.Y.	June 1964–67	23	22	21	19	17	13	12	10	9	8	8	7
		July 1964–67		24	23	23	21	17	12	11	10	10	10	8
		Aug. 1964–67	26	25	24	24	23	20	17	12	10	9	9	8
1–4265.00	West Branch Delaware River at Hale Eddy, N.Y.	June 1964–67	27	26	25	24	23	19	15	13	12	10	10	7
		July 1964–67	28	27	26	25	24	20	17	15	13	12	11	10
		Aug. 1964–67	27	27	26	25	24	21	18	16	12	10	10	8
1–4272.07	Delaware River at Lordville, N.Y.	June 1965–67	27	27	26	25	24	22	18	16	15	14	14	13
		July 1965–66	27	16	26	25	24	21	20	19	18	18	18	17
		Aug. 1965–66	27	27	26	25	24	21	18	18	17	16	16	15
1–4274.90	Delaware River at Callicoon, N.Y.	June 1964–67	28	28	27	26	25	22	19	18	17	16	16	14
		July 1964, 1966–67	29	29	28	27	26	24	22	22	21	20	20	18
		Aug. 1964–67	28	27	26	25	24	22	20	19	19	18	17	16
1–4277.40	Delaware River at Narrowsburg, N.Y.	June 1965–67	29	29	28	27	26	23	19	18	17	16	16	15
		July 1965–67	29	29	28	27	26	24	23	22	22	21	21	19
		Aug. 1965–66	29	28	27	27	25	23	21	21	19	18	18	17
1–4285.00	Delaware River above the Lackawaxen River near Barryville, N.Y.	June 1964–57	28	28	27	26	25	22	19	18	17	17	17	16
		July 1964–67	29	28	28	27	26	24	23	22	21	21	20	19
		Aug. 1964–66	27	27	26	25	24	23	21	20	19	18	18	16
1–4321.60	Delaware River at Barryville, N.Y.	June 1964–66	27	27	26	25	24	22	19	18	17	16	16	14
		July 1964–67	29	28	27	26	25	24	22	22	21	20	20	18
		Aug. 1964–66	27	26	26	25	24	23	22	21	20	17	17	16

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BASIC DATA

TABLE 4.—*Summary of water temperature records, in degrees Celsius, in the upper Delaware River basin, May–September 1963–67*

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
01-4215.00 East Branch Delaware River at Hancock, N.Y.																															
1964																															
May, max				17	17	18	18	19	20	20	17	17	18	18	17	19	20	19	19	19	17	17	22	24	24	21	22	21	18		
min					14	16	17	18	18	16	14	16	17	17	16	17	18	17	17	17	14	16	17	21	21	18	20	18	16		
June, max							18	19	19	22	24											28	28	27	25	24	26	26	27	28	
min							15	16	18	19	19												25	24	21	19	23	22	22	24	
July, max	28	28	28	28	26	25	25	25	24	25	27	27	25	26	26	27	28	28	28	29	28	28	28	26	24	24	28	27	25	21	18
min	26	26	26	26	23	22	22	22	22	22	23	24	23	22	24	23	24	26	26	26	27	25	25	24	23	23	24	25	21	17	16
August, max	17	17	18	19	18	17	17	18	18	16	17	18	17	17	17	17	16	15	14	14	14	14	16	17	17	17	16	17	17	18	17
min	16	17	16	17	16	16	15	17	16	14	15	17	16	16	15	14	14	14	13	13	13	13	13	15	16	14	13	14	15	16	16
September, max	17	17	17	17	17	17	17	17	17	17	17	17	14	14	14	13	16	16	16	16											
min	15	14	14	16	16	14	14	14	15	14	16	14	13	13	13	12	13	14	15	14											
1965																															
May, max						17	16	11	17	19	19	21	19	18	19	20	21	19	19	20	20	19	20	20	21	23	23	23	21	17	15
min						14	11	10	11	16	18	18	18	16	16	18	19	17	17	18	17	18	18	17	18	20	22	21	17	14	13
June, max	15	14	16	18	21	22	24	24	27	26	23	21	18	13	14	18	18	18	22	23	24	27	25	25	23	24	23	25	26	25	
min	13	13	12	14	16	18	21	22	23	23	20	17	13	12	11	14	16	17	17	19	21	23	22	23	21	19	20	21	24	21	
July, max	24	24	22	25	23	24	23	24	26	26	23	25	26	27	26	26	25	25	23	21	23	21	22	24	27	26	24	23	21	21	21
min	19	21	21	21	22	22	20	20	23	23	22	21	22	23	24	22	23	22	21	19	18	19	19	21	24	24	21	21	19	18	18
August, max	21	19	19	21	23	24	27	26	26	26	25	25	24	26	27	28	28	27	26	24	22	21	22	22	22	22	23	23	19	17	16
min	19	19	18	17	20	22	24	25	25	24	22	22	23	23	24	26	26	26	24	22	21	19	19	19	20	21	21	19	16	15	15
September, max	16	19	20	19	19	21	23	22	21	23	22	19	17	17	17	18	18	19	22	23	24	25	24	23	18	16	15	13	14	14	
min	15	16	16	18	18	18	21	21	19	19	19	17	15	15	16	16	17	17	19	21	22	23	23	18	15	14	13	12	13	13	
1966																															
May, max	9	9	10	9	10	12	11	11	10	8	9	9	9	11	13	13	13	13	12	14	13	16	17	18	18	18	18	18	17	16	15
min	9	8	8	8	7	10	9	10	7	6	7	8	8	8	10	12	11	12	12	12	13	13	13	16	16	16	17	17	16	15	14
June, max	14	16	19	21	22	22	21	22	21	20	15	17	18	19	21	19	18	20	21	22	22	23	23	24	26	26	27	27	27	26	
min	14	13	14	17	19	21	21	20	20	14	13	14	16	18	18	15	16	17	18	19	20	20	20	22	22	23	24	24	25	24	
July, max	27	27	28	26	25	26	26	24	24	25	26	28	28	26	23	23	24	24	24	22	22	23	23	23	25	25	24	23	23	22	23
min	23	24	26	24	24	24	23	22	22	23	24	24	26	23	22	22	22	22	22	21	21	21	22	22	23	24	23	22	22	21	21
August, max	23	23	23	22	22	24	26	25	24	26	25	24	21	16	14	13	16	16	14	15	14	14	16	14	13	14	14	14	14	14	16
min	22	23	22	21	21	22	24	24	23	24	24	21	16	14	13	13	13	14	13	12	13	13	14	13	12	13	12	13	13	12	14
September, max	17	15	13	12	13	14	14	12	11	11	11	11	10	10	9	9	9	10	11	11	11	10	12	11	10	9	9	9	9	9	
min	15	12	12	10	10	13	12	11	9	9	10	9	9	9	9	9	8	10	9	10	9	9	10	10	9	8	8	8	8	8	
1967																															
May, max																															
min																															
June, max																															
min																															

July, max																															
min																															
August, max									19	19	19	18	18	21	22	23	23	23	23	23	21	22	22	21	19	18	19	19	20	21	21
min									18	18	17	17	17	17	18	19	21	21	22	21	19	20	20	19	18	18	18	18	18	19	17
September, max	18	17	18	20	19	21	21	21	20	19	16	17	17	19	19	21	21	22	21	21	21	19	15	13	12	14	16	17			
min	15	16	15	17	19	18	19	18	19	14	13	14	16	16	17	18	19	21	20	20	19	15	13	11	11	11	14	16	17		

01–4250.00 West Branch Delaware River at Stilesville, N.Y.

1963																															
May, max	13	12					16	16	19	19	17	12	13	14	14	17	17	16	15	15	14	15	15	13	16	16	17	17	14	16	19
min	11	9					13	14	15	17	11	9	11	13	12	13	14	13	13	13	12	13	11	9	11	14	12	14	14	14	14
June, max	21	22	22	21	22	24	24	22	23	23	22	19	18	18	17	19	20	22	24	24	22	19	22	24	26	27	26	28	27	28	
min	17	19	19	21	20	21	22	19	19	22	19	16	15	16	17	16	17	18	20	22	17	16	18	20	22	23	24	24	26	24	
July, max	29	31	28	22	22	22	23	22	22	21	21	26	25	25	22	24	27	28	27	26	23	24	25	27	28	28	29	29	28	28	26
min	26	27	22	19	20	20	21	20	18	18	19	20	23	22	21	21	23	26	26	23	22	22	22	23	24	26	27	27	28	26	23
August, max	25	22	22	22	22	22	22	21	22	21	21	20	20	24	17	19	18	18	17	18	21	23	25	23	21	19	21	21	21	23	22
min	22	19	20	21	18	18	20	19	19	19	19	19	19	16	15	17	18	17	17	17	18	20	21	21	19	19	19	19	19	19	20
September, max	20	22	21	21	19	18	20	23	22	22	21	21	20	18	19	18	18	21	21	21	19	16	15	15	16	18	18	18	18	16	
min	18	19	20	19	18	17	18	19	20	21	19	20	17	16	16	17	18	18	18	19	16	15	13	13	14	13	16	17	16	14	
1964																															
May, max	6	6	7	7	7	8	7	7	7	7	9	9	9	8	9	10	10	9	10	9	11	11	11	12	11	13	14	13	9	11	11
min	6	6	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8	8	8	8	8	8	9	9	9	9	12	9	8	8	9
June, max	9	10	9	10	10	9	9	12	16	16	17	16	11	12	11	12	12	12	12	13	13	14	15	14	14	15	17	16	17	17	
min	9	9	8	8	9	9	9	9	12	13	12	11	10	11	11	10	10	11	11	12	12	12	13	13	13	14	14	15	16	16	
July, max	17	17	17	17	18	18	18	18	19	19	20	20	19	21	19	20	20	20	21	22	22	22	24	22	22	23	24	24	23	22	23
min	16	16	16	16	16	17	17	18	18	18	19	19	18	19	19	19	19	19	19	20	21	21	20	21	21	21	21	21	21	21	21
August, max	23	22	23	24	23	23	23	22	20	21	22	21	19	19	19	20	20	19	19	19	18	19	19	20	22	20	22	21	22	23	22
min	20	21	21	20	21	21	20	20	19	19	19	19	19	18	18	18	18	18	18	18	18	18	19	18	18	19	19	18	19	19	23
September, max	21	21	22	23	22	22	24	23	21	24	23	19	21	21	19	19	20	21	18	19	19	20	21	18	14	18	16	14	13	14	
min	19	19	19	20	19	17	18	18	18	19	18	16	14	14	14	13	14	13	16	15	14	14	14	13	13	13	13	12	13	12	
1965																															
May, max	9	10	10	9	11	11	4	7	12	11	12	14	12	13	15	13	10	12	13	15	16	13	13	17	16	18	16	18	12	12	14
min	1	2	2	2	2	1	2	3	4	4	5	4	4	3	4	5	7	7	7	7	7	8	9	7	8	9	10	9	9	7	8
June, max	12	9	16	17	18	19	19	16	18	17	17	18	10	10	11	13	9	10	11	13	14	13	13	14	13	14	14	14	15	12	
min	8	9	8	7	8	8	10	10	11	9	8	9	8	7	7	7	7	8	8	8	8	8	8	9	8	8	8	8	9	9	
July, max	12	18	16	16	12	16	13	16	16	15	14	19	21	19	18	19	19	16	18	18	18	17	21	20	24	21	17	16	18	19	19
min	9	8	10	9	9	10	9	12	11	12	10	9	10	11	12	11	12	13	13	11	11	12	14	13	15	12	13	13	13	13	17
August, max	18	18	18	19	20	21	22	20	22	21	23	22	21	22	22	24	26	24	25	25	24	22	24	24	24	21	22	22	18	19	16
min	17	17	18	17	18	18	18	19	19	19	19	19	19	19	19	19	22	22	23	22	21	20	19	19	18	19	19	17	16	15	14
September, max	16	19	21	19	19	23	24	20	20	24	21	19	18	20	18	18	18	19	22	22	24	25	25	22	21	22	18	17	16	16	
min	15	15	16	16	16	17	19	18	19	19	18	18	17	17	17	16	17	17	19	18	19	20	22	21	18	17	13	14	15	15	

TABLE 4.—*Summary of water temperature records, in degrees Celsius, in the upper Delaware River basin, May–September 1963–67*—Con.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
01-4250.00 West Branch Delaware River at Stilesville, N.Y.—Continued																															
1966																															
May, max	8	11	12	7	12	12	14	9	8	11	12	8	11	16	19	12	13	10	13	16	12	16	19	18	16	19	17	14	18	13	15
min	6	5	4	4	4	7	5	7	5	4	5	7	8	8	8	8	7	9	10	9	9	9	8	9	10	8	9	11	11	8	8
June, max	14	16	19	20	21	17	16	19	18	14	19	21	20	18	17	12	18	21	21	21	21	21	21	11	11	11	17	21	12	12	----
mim	8	8	8	11	11	11	11	11	11	10	9	10	10	11	11	10	11	10	10	10	11	10	10	10	10	9	9	12	9	11	----
July, max	9	9	9	9	10	9	10	9	11	11	10	15	15	12	13	13	15	12	12	13	14	14	14	16	16	16	18	18	19	21	21
min	9	9	9	9	9	9	9	9	9	9	10	9	10	11	11	11	11	12	12	12	12	13	14	14	15	16	17	17	18	18	19
August, max	22	21	22	23	23	23	24	23	23	23	23	23	24	23	23	23	26	28	23	24	23	24	26	23	23	22	24	23	24	23	26
min	19	21	21	21	22	22	22	23	23	23	23	22	22	22	22	22	21	20	22	19	22	22	21	19	21	22	22	22	21	21	20
September, max	25	23	22	21	24	22	21	21	21	21	19	20	19	18	17	18	19	21	20	16	14	14	15	13	14	15	14	14	13	13	----
min	19	19	20	19	19	18	18	18	20	19	19	18	18	17	16	13	14	15	15	14	13	14	13	12	11	11	11	13	12	12	----
1967																															
May, max	14	10	9	9	9	9	7	7	7	6	6	7	6	7	7	7	6	7	7	7	7	9	11	13	12	12	14	14	14	15	17
min	5	7	6	4	5	6	4	4	6	6	6	6	6	6	6	6	6	6	7	7	7	7	9	11	12	12	12	13	14	13	13
June, max	19	22	23	23	24	19	21	17	14	14	13	14	14	13	13	14	21	17	16	19	22	19	21	21	18	20	24	24	23	22	----
min	13	13	14	15	16	12	11	10	10	12	11	11	11	11	10	10	12	13	13	11	11	13	14	13	13	12	12	18	21	21	----
July, max	24	23	23	24	23	23	23	22	23	24	23	24	24	23	22	19	20	18	21	21	12	13	17	17	20	21	20	17	14	19	16
min	22	22	22	22	22	22	21	17	21	22	22	22	21	21	11	12	13	12	12	12	11	10	11	13	13	13	12	13	11	12	11
August, max	16	21	20	21	21	21	20	21	19	21	19	18	17	21	18	13	10	11	9	11	11	12	12	9	11	11	13	14	18	17	13
min	12	13	13	14	14	13	13	15	14	14	12	12	12	12	12	8	8	8	8	8	8	8	8	8	8	8	10	11	9	10	10
September, max	15	15	11	17	17	13	12	11	11	11	15	16	12	12	12	8	11	11	11	12	9	8	8	8	9	10	12	12	14	9	----
min	8	8	8	9	9	9	8	8	8	10	7	8	9	8	8	8	8	8	8	8	8	8	8	8	8	8	9	9	9	9	----
01-4265.00 West Branch Delaware River at Hale Eddy, N.Y.																															
1964																															
May, max	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	16	16	13	17	17	19	20	17	17	22	13	13	18	15
min	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	11	9	10	7	8	16	11	12	8	14	14	10	8	9
June, max	13	16	12	14	16	11	12	16	23	25	24	24	17	18	14	17	18	17	14	19	22	22	20	18	16	21	21	21	22	22	----
min	10	9	9	10	7	7	9	10	14	17	16	16	11	10	10	11	9	12	11	12	13	15	13	15	13	13	14	13	14	16	----
July, max	20	23	21	21	21	22	23	20	22	23	24	23	20	26	23	26	25	25	26	27	27	26	26	24	23	24	29	28	27	24	25
min	16	17	17	17	16	16	16	17	18	18	18	19	18	19	18	18	19	21	21	22	22	22	21	22	21	21	22	22	23	20	18
August, max	24	25	26	26	25	24	25	25	21	22	23	23	21	19	21	21	22	21	18	19	19	19	23	24	24	21	24	24	24	26	26
min	18	21	21	19	20	19	17	21	18	16	18	21	17	16	15	16	18	18	17	18	17	17	19	21	18	18	16	21	19	21	22
September, max	23	23	24	26	24	24	24	24	24	27	26	21	20	21	19	18	21	21	20	19	20	21	23	21	17	19	18	16	14	14	----
min	21	17	17	19	21	16	16	17	19	21	21	17	12	12	13	10	14	14	15	13	14	13	15	16	13	12	13	12	12	11	----

1965																															
May, max						20	15	13	21	21	22	22	20	20	22	22	18	18	19	22	22	19	20	22	22	26	24	24	19	17	17
min							8	7	11	16	17	13	14	11	12	14	14	13	12	13	13	14	15	12	14	17	19	18	14	11	10
June, max	18	15	19	21	23	24	27	26	27	25	25	26	21	17	15	21	17	17	21	23	24	25	24	24	23	24	24	25	26	21	
min	12	13	11	11	13	14	18	20	19	19	16	16	14	13	12	12	13	12	12	13	16	18	17	18	15	13	14	16	19	17	
July, max	24	24	23	26	22	24	18	25	26	24	23	26	27	28	28	27	26	26	24	21	24	20	24	27	30	28	24	23	22	24	22
min	14	17	17	17	18	16	16	16	18	20	17	15	17	19	22	18	20	20	18	14	15	17	17	21	23	21	19	18	16	16	16
August, max	19	20	19	22	24	25	25	22	24	24	24	26	22	25	27	27	27	27	26	26	23	21	24	24	23	22	24	23	17	19	16
min	17	16	17	15	17	18	18	19	19	20	18	18	18	18	19	19	21	23	23	20	17	17	17	16	16	18	19	17	13	11	12
September, max	15	21	22	23	21	23	25	21	19	24	22	16	15	18	17	20	18	21	23	26	26	26	27	23	18	18	17	15			
min	13	13	14	16	14	15	17	18	18	17	18	15	13	13	16	14	16	16	18	19	21	21	21	17	14	12	11	9			
1966																															
May, max																			16	18	16	19	21	22	21	23	22	21	22	17	18
min																				13	14	13	13	15	14	14	16	18	16	13	12
June, max	17	19	22	26	27	26	23	26	24	20	18	20	23	23	21	18	22	24	26	26	27	27	27	23	19	21	23	28	27	26	
min	12	12	12	17	19	21	19	19	19	13	12	13	14	18	17	15	14	16	17	18	19	18	18	13	12	14	14	20	23	17	
July, max	19	17	18	14	15	16	16	16	17	20	18	21	21	17	18	18	19	19	17	19	18	18	19	21	22	21	21	21	23	23	25
min	11	10	10	10	11	11	11	10	10	12	12	11	12	13	12	12	12	13	13	13	13	15	15	15	16	17	18	18	19	18	18
August, max	25	22	23	24	24	26	25	25	25	26	26	24	24	23	24	23	26	27	25	27	23	27	27	23	24	24	25	25	25	27	26
min	19	20	20	19	20	21	21	21	21	22	21	21	19	19	19	22	20	19	22	19	20	22	23	20	19	21	19	21	21	21	22
September, max	26	26	24	21	23	22	19	21	22	22	21	19	19	18	16	18	19	20	20	17	14	14	14	13	14	14	14				
min	22	21	22	19	18	18	17	15	16	17	17	16	17	16	13	12	14	14	15	14	13	13	12	11	10	10	9				
1967																															
May, max												10	10	9	8	8	9	10	11	10	10	10	11	13	12	12	16	17	11	16	18
min													6	7	7	7	6	7	7	8	8	8	7	9	9	9	9	11	11	9	9
June, max	21	23	23	26	27	25	26	25	21	25	24	24	25	18	16	15	24	22	18	20	26	24	23	26	23	23	24	24	19	19	
min	11	13	14	17	17	18	17	19	10	16	16	14	14	14	10	9	15	19	16	14	16	21	19	19	20	16	17	18	18	17	
July, max	23	23	24	24	21	23	24	22	23	24	25	24	24	24	22	21	25	23	26	27	24	16	18	19	23	26	25	22	20	22	26
min	18	20	17	18	18	17	17	18	16	19	21	19	19	19	17	14	18	19	19	20	10	10	11	17	17	18	18	18	15	15	21
August, max	25	24	22	23	24	24	24	22	21	22	21	21	19	24	25	21	14	13	12	12	20	16	16	14	11	12	17	19	23	23	22
min	17	18	19	19	18	18	18	18	18	18	16	16	17	16	17	13	9	8	8	10	12	11	9	8	8	10	12	17	16	17	14
September, max	19	19	21	21	23	24	16	13	13	13	15	19	20	14	13	11	13	13	13	13	13	11	8	8	11	12	13	13	18	17	
min	13	13	12	13	16	16	12	8	10	11	9	12	13	8	7	7	8	8	8	8	9	8	7	7	7	7	7	9	13	8	

01-4272.07 Delaware River at Lordville, N.Y.

1964																															
May, max																						17	20	22	22	19	19	19	16	16	17
min																							16	18	19	16	17	16	14	13	14
June, max	17	17	17	14	16	16	14	14															24	23	21	19	22	22	22	23	
min	16	14	14	13	13	14	12																22	21	17	16	19	19	19	21	
July, max	23	23	24	24	22	21	22	22	20											27	26	26	26	25	23	24	27	28	27	24	21
min	22	21	22	22	19	19	19	21	18											24	24	23	23	23	23	22	23	25	24	21	19
August, max	19	19	20	21	19	19	19	20	20	18	18	19	19	17	17	17															19
min	17	18	18	18	18	17	17	19	18	16	16	18	17	16	16	15															
September, max	19	17	17	18	18	18	17	18	18	18	18	17	14	13	13	12	14	15	15	14	14	14	16	16	14	13					
min	17	15	16	17	17	16	16	16	17	17	17	14	13	12	12	11	12	13	13	13	13	13	13	14	12	11					

TABLE 4.—*Summary of water temperature records, in degrees Celsius, in the upper Delaware River basin, May–September 1963–67*—Con.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
01-4272.07 Delaware River at Lordville, N.Y.—Continued																															
1965																															
May, max	12	14	17	16	18	17	14	10	16	18	20	19	18	17	18	19	19	17	17	20	19	18	18	19	20	23	22	22	20	17	16
min	9	12	13	14	14	14	10	9	10	16	18	16	17	14	14	16	17	15	14	16	16	17	17	16	17	19	21	20	17	15	14
June, max	15	14	15	17	19	22	24	24	26	26	23	23	21	16	14	18	17	18	19	22	23	26	26	24	23	23	23	24	26	24	
min	14	14	12	13	16	18	21	23	23	23	21	20	16	14	13	14	16	16	16	18	21	22	23	23	21	19	19	21	23	21	
July, max	23	24	22	24	24	23	21	22	24	24	23	24	26	27	26	26	25	25	23	22	22	21	22	23	26	26	24	22	22	22	21
min	20	21	21	21	22	21	20	19	22	23	22	21	22	23	25	23	24	23	22	20	19	20	19	21	23	24	22	21	21	19	19
August, max	21	19	18	20	22	24	26	26	25	26	24	24	23	24	26	28	27	27	26	25	23	22	21	22	22	26	22	22	19	17	15
min	18	18	18	17	19	21	23	24	23	24	22	22	22	22	23	24	24	25	25	23	22	19	19	19	19	21	19	19	16	15	15
September, max	15	17	19	19	18	20	22	21	21	21	21	21	19	17	16	18	17	18	21	23	24	24	24	23	21	17	14	13	13	13	
min	15	15	16	18	17	17	19	20	19	20	19	19	17	15	15	16	17	16	18	21	22	22	22	20	17	14	12	12	12	12	
1966																															
May, max	9	10	11	9	10	12	12	12	11	8	9	9	9	11	14	13	14	14	13	16	15	16	18	18	19	19	19	19	19	17	16
min	9	8	8	8	7	10	10	11	8	7	7	9	9	9	11	13	11	13	12	13	14	14	14	16	17	17	18	19	17	16	15
June, max	16	16	18	21	23	23	22	23	22	21	16	18	19	21	21	19	18	21	22	23	24	24	24	24	24	24	26	27	28	27	
min	14	14	15	18	20	22	22	21	21	16	14	16	17	19	19	17	16	17	19	20	22	22	22	22	22	22	23	24	25	24	
July, max	26	22	22	20	18	19	19	19	19	22	23	22	23	22	21	18	19	21	21	19	19	19	19	20	21	22	21	20	22	21	23
min	22	21	20	18	17	18	18	18	17	18	21	21	19	21	18	17	17	18	18	18	17	17	18	18	19	21	20	20	19	20	19
August, max	23	21	21	21	22	23	23	24	23	24	24	23	22	20	19	18	18	19	19	19	18	19	19	18	17	18	18	18	19	18	
min	21	21	19	19	21	21	21	22	22	23	23	22	20	19	18	17	17	17	18	17	17	17	18	16	16	16	16	18	17	17	
September, max																															
min																															
1967																															
May, max												8	10	10	10	9	10	12	12	12	11	11	13	13	13	12	14	17	17	15	16
min												7	8	9	9	8	8	9	11	11	10	10	10	12	12	11	12	14	13	13	13
June, max	18	19	21	22	23	23	23	23	25	24	25	26	26	26	22	22	24	24	23	19	21	22	21	19	20	19	19	21	20	18	
min	15	17	18	21	21	22	21	23	23	23	24	24	25	22	21	21	21	23	19	18	18	21	19	19	19	18	18	19	18	18	
July, max	21	23	23	23	23	20	21	22	23																						
min	18	21	22	22	19	19	19	21	22																						
August, max																															
min																															
September, max																															
min																															
01-4274.90 Delaware River at Callicoon, N.Y.																															
1964																															
May, max				17	15	16	17	17	19	19	17	17	18	18	18	18	20	20	20	20	18	21	23	24	24	22	22	21	19	19	19
Min				14	13	14	14	16	18	17	15	15	16	17	16	16	17	18	18	18	16	17	19	21	22	19	20	18	17	16	17

June, max	19	19	19	18	19	19	17	18	19	23	21	21	23	25	25	22	20	21	21	22	26	26	26	25	23	23	24	25	24	26	
min	18	17	17	16	16	16	16	17	18	19	18	18	22	22	22	19	17	18	19	19	22	24	25	23	20	19	22	22	23	23	
July, max	26	26	26	25	24	23	23	23	22	24	25	25	24	24	25	26	27	27	27	30	28	28	28	26	24	25	28	28	29	28	25
min	24	24	24	24	22	22	22	22	21	21	23	24	22	22	24	24	24	26	26	27	27	26	26	24	24	24	25	27	28	25	24
August, max	23	23	23	24	23	23	22	22	21	20	21	21	20	19	19	22	21	20	20	20	19	19	20	21	22	22	22	21	22	24	24
min	22	22	22	21	22	22	20	21	19	19	19	20	19	17	18	18	19	19	19	19	19	19	19	19	21	16	19	19	21	22	23
September, max	23	23	21	21	23	22	22	22	22	22	23	22	19	17	17	16	17	17	17	16	17	17	18	18	17	16	16	16	14	14	
min	23	21	20	20	21	21	20	21	21	21	22	19	17	16	16	14	14	16	16	16	16	16	17	17	16	14	15	14	14	13	
1965																															
May, max	14	17	18	18																22	21	20	21	22	22	24	24	24	23	19	19
min	11	12	14	16	16																17	18	19	17	18	21	22	22	19	17	16
June, max	18	18	18	19	22	24	26	27	28	26	26	25	22	18	17	19	18	19	22	24	25	27	26	26	25	25	24	26	27	26	
min	16	16	16	15	17	18	22	23	24	24	21	21	17	15	16	15	16	17	17	19	21	23	24	24	22	21	21	22	24	22	
July, max	26	24	24	26	24	26	25																							23	23
min	21	22	21	22	23	23	23																							21	21
August, max	22	20	19	22	24	26	26	26	26	27	27	26	24	27	28	29	28	28	27	26	24	23	23	23	23	23	23	23	20	18	17
min	20	19	18	18	20	22	23	24	24	24	23	23	23	23	24	25	26	26	26	24	22	21	20	20	20	21	21	20	17	16	16
September, max	16	19	20	21	21	22	23	22	21	24	23	21	18	18	18	19	19	21	23	24	25	26	26	25	21	18	17	15	14	14	
min	16	16	17	18	18	18	21	21	20	19	21	18	17	16	17	17	18	18	21	22	23	24	24	20	18	17	14	13	13	14	
1966																															
May, max	10	10	11	11	10	12	12	12	12	9	9	9	10	11	13	14	14	14	13	16	16	16	18	19	21	21	19	20	20	18	17
min	9	9	9	9	8	10	11	12	9	8	8	9	9	9	11	13	13	13	13	13	16	16	15	17	18	18	19	19	18	17	16
June, max	17	17	19	22	24	24	24	24	24	22	17	18	20	22	22	21	21	22	23	24	26	26	26	27	28	27	28	28	29	28	
min	16	15	15	18	21	22	23	22	22	17	16	16	18	20	21	18	18	18	20	21	22	22	22	23	24	24	24	26	26	26	
July, max	29	28	27	24	23	23	23	22	23	24	25	29	27	26	25	23	23	24	24	23	23	23	22	23	24	24	24	23	24	23	25
min	24	24	24	23	22	21	21	21	19	21	22	23	24	24	22	20	19	20	22	20	19	20	21	20	22	23	23	22	22	21	21
August, max	26	24	23	23	23	24	26	26	25	26	26	24	24	23	22	21	22	23	22	23	21	22	23	21	21	20	21	21	22	22	22
min	22	23	21	21	22	23	24	24	24	24	24	22	22	22	21	20	20	19	21	20	20	20	21	20	18	19	18	19	19	20	20
September, max	22	21	21	18	16	16	16	17	17	17	17	17	15	15	14	14	15	16	16	16	14	12	12	13	12	12	13	12	12	12	
min	21	18	18	16	15	14	15	15	15	14	15	15	14	14	13	11	12	13	14	14	12	12	12	12	11	11	11	11	12	12	
1967																															
May, max												7	9	9	9	8	9	11	12	12	12	11	12	13	13	12	14	17	17	16	17
min												6	7	9	8	8	8	9	11	12	11	9	9	12	12	11	11	14	14	13	13
June, max	19	21	22	23	24	24	24	25	26	26	26	28	27	26	23	26	26	24	22	19	21	22	21	20	20	19	20	21	20	19	
min	14	16	17	19	21	21	21	23	23	23	24	24	25	22	21	22	23	22	19	18	18	21	19	19	19	19	19	19	19	18	
July, max	21	23	24	24	23	21	22	23	24	27	24	24	24	24	24	21	23	22	24	27	26	24	22	22	24	26	26	26	23	24	26
min	18	21	22	22	21	19	19	21	22	24	23	23	23	22	21	20	20	21	22	23	24	21	20	21	21	22	23	23	21	21	22
August, max	26	26	25	24	23	22	23	23	21	20	21	20	19	21	23	24	23	23	22	21	21	22	22	21	20	18	18	18	20	21	21
min	23	23	24	23	22	21	21	21	20	20	19	19	19	19	20	21	22	22	21	20	19	19	20	20	18	17	17	18	18	19	19
September, max	18	18	19	20	23	21	22	22	22	21	17	18	18	19	20	20	19	20	21	20	19	18	16	13	11	13	14	15			
min	17	16	16	17	18	19	20	19	21	16	14	14	16	17	17	18	17	18	18	18	18	10	13	11	10	10	12	14	15		

TABLE 4.—*Summary of water temperature records, in degrees Celsius, in the upper Delaware River basin, May–September 1963–67*—Con.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
01-4277.40 Delaware River at Narrowsburg, N.Y.																															
1965																															
May, max	14	16	18	19	19	20	17	13	16	19	22	21	20	19	21	21	21	19	20	21	21	20	21	21	22	24	24	25	22	18	19
min	11	13	14	16	16	16	12	12	13	16	19	18	17	16	16	17	19	17	16	18	17	18	18	17	18	20	22	22	17	16	15
June, max	18	17	18	19	21	23	26	26	28	27	26	26	23	20	18	19	19	19	21	24	25	27	27	26	24	24	24	26	27	25	----
min	16	16	16	16	17	18	21	23	24	24	22	21	19	18	16	15	17	17	18	18	21	23	23	24	21	20	21	21	23	22	----
July, max	25	26	24	26	24	25	23	25	26	25	24	26	26	28	28	27	26	27	25	24	25	22	24	26	28	27	24	24	23	22	23
min	21	21	21	22	23	22	21	21	22	23	23	21	23	24	26	23	24	24	23	21	21	21	21	23	24	24	23	22	21	20	21
August, max	22	21	20	22	24	26	26	27	27	28	26	27	24	26	28	29	28	28	27	26	24	23	23	23	23	23	23	24	21	18	17
min	21	20	19	18	21	22	24	24	24	25	23	23	23	23	24	26	26	26	26	23	21	21	20	19	20	21	21	21	17	16	16
September, max	17	19	21	21	20	23	24	23	22	23	22	19	18	18	18	20	19	21	23	24	26	26	26	25	21	18	17	15	14	14	----
min	16	16	17	18	18	18	21	21	21	20	19	18	17	16	17	17	17	17	19	22	23	23	23	21	18	16	15	13	13	14	----
1966																															
May, max	9	10	11	10	10	12	12	12	11	8	9	9	9	11	13	13	14	14	13	16	15	16	17	18	18	20	19	19	19	18	17
min	9	9	8	8	8	10	10	11	8	7	7	9	9	9	11	12	13	13	13	13	15	15	15	17	17	18	19	19	18	17	16
June, max	17	17	19	22	24	23	23	24	24	22	18	17	19	21	23	21	21	22	23	25	26	27	27	27	28	28	29	28	29	29	----
min	16	15	16	18	20	22	22	22	22	18	16	16	17	19	20	19	18	19	20	21	22	23	23	24	24	26	26	26	26	26	----
July, max	29	31	29	27	26	25	26	24	24	25	27	29	29	27	26	24	23	24	24	23	23	23	22	23	24	25	25	24	24	23	24
min	24	25	27	26	24	23	23	23	21	22	23	24	26	23	23	22	21	21	22	21	21	21	22	21	22	23	23	22	22	21	21
August, max	26	24	23	23	23	25	24	25	24	26	24	24	23	22	22	21	22	23	23	23	22	23	23	22	21	21	22	22	22	22	23
min	22	22	21	21	22	22	23	23	24	24	24	23	22	21	21	21	21	21	22	21	21	21	22	21	19	20	19	20	21	21	21
September, max	24	23	21	19	18	18	18	17	18	18	18	17	16	16	16	15	16	16	16	17	16	13	12	13	12	13	12	12	12	11	----
min	21	19	19	17	17	17	16	16	16	16	16	16	16	16	15	13	13	14	15	16	13	12	12	12	11	11	11	11	11	9	----
1967																															
May, max												9	11	11	11	10	11	12	14	14	13	12	13	14	14	12	15	18	17	17	18
min												8	9	11	10	9	9	11	12	13	12	11	11	11	12	12	12	15	14	14	14
June, max	19	21	24	27	27	27	27	28	28	27	27	28	28	26	25	27	27	26	23	21	22	23	23	22	21	21	22	22	22	21	----
min	16	13	19	21	23	24	24	25	25	24	24	25	26	22	22	22	25	23	21	19	19	22	21	21	21	20	20	20	21	19	----
July, max	23	24	25	24	24	22	23	24	26	27	26	24	24	25	24	22	24	23	24	26	25	24	23	22	24	26	27	26	23	24	26
min	19	22	23	23	22	21	21	22	23	24	24	23	23	23	21	21	21	22	22	23	24	22	21	22	22	23	23	23	22	22	23
August, max	26	26	24	24	23	23	23																								
min	23	23	24	23	23	22	22	22																							
September, max																															
min																															

01-4285.00 Delaware River above the Lackawaxen River near Barryville, N.Y.

1964																															
May, max																												21	20	21	21
min																												18	17	16	17
June, max	19	21	18	19	20	18	18	19	19	23	23	23	22	24	23	22	22	22	21	24	26	27	26	26	24	25	25	26	26	26	----
min	18	17	16	16	16	16	16	17	18	18	19	19	21	21	21	19	17	18	19	20	22	23	24	24	22	21	22	21	22	23	----
July, max	26	26	27	26	24	24	24	23	22	24	26	24	23	24	24	26	27	27	28	28	29	28	29	27	25	24	27	28	28	27	26
min	24	24	24	23	22	21	21	21	21	19	21	22	21	21	22	22	23	24	25	26	26	26	26	25	23	23	24	26	26	25	23
August, max	26	25	25	25	24	24	24	24	22	22	22	24	22	21	21	20	21	22	21	20	20	21	21	22	23	22	23	22	22	23	24
min	22	23	23	22	22	21	21	22	21	19	20	21	20	19	18	18	18	19	18	18	18	18	19	19	20	21	19	19	19	21	22
September, max	24	23	23	23	23	23	23	23	23	24	24	22	20	20	18	18	19	19	18	18	18	19	20	19	17	18	17	16	15	15	----
min	22	21	19	21	21	20	19	20	21	21	22	20	18	17	16	14	16	16	16	16	16	16	17	17	16	15	15	15	14	14	----
1965																															
May, max					19	19	18	14	16	18	20	21	20	19	20	20	21	19	20	21	21	20	21	21	21	23	23	24	22	19	19
min						16	14	13	13	15	18	18	18	16	16	17	19	17	16	17	17	18	18	17	18	20	21	22	19	17	16
June, max	19	18	19	19	20	22	24	26	26	26	25	25	24	21	19	19	18	19	20	22	23	24	25	24	24	24	24	24	25	24	----
min	16	17	16	16	16	18	21	22	23	24	22	22	19	18	17	16	17	17	17	18	20	22	23	23	21	20	21	21	23	22	----
July, max	24	24	23	24	24	24	23	24	25	24	24	24	25	26	26	26	26	26	24	24	24	23	23	24	25	25	24	23	23	22	23
min	21	21	21	21	22	21	21	21	22	24	22	21	22	23	24	23	23	24	23	21	21	21	21	22	23	23	22	21	21	20	20
August, max	22	21	21	22	22	24	24	25	26	26	26	26	24	25	26	27	27	27	27	26	24	23	23	23	23	22	24	23	24	19	17
min	21	20	19	18	20	22	23	23	24	24	24	23	23	22	24	25	26	26	26	24	22	21	20	20	20	21	21	21	18	17	16
September, max	17	19	20	19	20	21	22	22	21	22	22	21	18	18	18	19	19	20	22	23	24	24	25	24	21	18	17	16			
min	16	16	17	18	19	18	19	20	20	19	21	18	17	17	17	17	18	17	19	21	22	22	23	21	18	16	15	14			
1966																															
May, max																										22	21	21	20	19	18
min																										19	20	19	16	16	18
June, max	18	18	19	21	22	23	23	24	24	24	18	18	18	19	22	21	21	22	23	24	25	26	26	26	27	27	28	28	28	28	----
min	16	16	16	18	19	22	22	22	22	18	16	16	17	18	19	19	18	18	19	20	22	22	22	24	24	24	25	26	25	26	----
July, max	28	29	29	28	27	27	26	26	25	26	26	28	28	28	28	26	25	25	26	24	24	24	23	24	25	26	26	24	24	23	24
min	25	26	26	27	25	24	24	23	21	22	23	24	26	26	24	22	22	22	23	22	20	21	22	21	22	23	23	23	23	21	21
August, max	26	24	23	23	24	24	26	26	26	26	26	26	26	24	23	23	23	24	25	25	23	24	24	24	23	23	23	23	23	24	24
min	22	23	21	20	21	22	23	23	23	24	24	24	22	21	21	22	21	21	22	22	21	22	23	21	20	20	19	20	21	22	22
September, max	26	25	23	22	21	21	20	21	21	21	21	19	19	18	18	18	19	18	19	18	15	15	16	14	15	16	14				
min	22	22	22	21	19	18	18	18	18	18	18	17	17	17	16	14	15	15	16	16	14	14	13	13	13	12	12				
1967																															
May, max										8	8	8	11	11	11	11	13	15	15	16	13	13	15	15	14	13	16	19	18	18	19
min												7	8	11	10	10	11	13	13	14	13	12	13	14	13	13	12	15	16	15	15
June, max	21	22	23	25	26	25	24	25	26	27	26	27	28	24	26	27	28	26	23	21	22	22	22	22	22	22	21	23	21	19	----
min	16	20	19	19	21	22	21	22	22	24	23	23	24	22	25	23	24	23	20	19	18	20	21	21	21	20	20	20	20	19	----
July, max	23	24	26	26	23	23	23	24	26	24	26	24	25	26	24	23	24	24	24	26	26	24	23	23	25	26	27	25	24	24	26
min	19	21	22	22	22	20	20	20	19	21	24	23	22	23	21	21	21	22	22	22	23	22	22	21	22	21	21	23	22	21	22
August, max	26	26	24	24	24	22	24	24	23	22	22	21	21	22	23	24	24	25	25	23	22	23	22	23	23	18	19	20	21	23	22
min	23	24	23	23	22	21	21	22	21	20	20	19	19	19	19	21	22	22	23	22	21	20	20	19	18	18	18	18	19	21	18
September, max	23	21	21	23	23	23	24	25	24	23	21	21	21	22	23	22	23	24	24	23	22	21	18	15	16	16	17	18	18	19	----
min	19	19	18	19	21	21	22	22	22	21	18	18	18	19	19	20	21	21	21	21	21	18	16	14	13	13	14	16	17	17	----

TABLE 4.—*Summary of water temperature records, in degrees Celsius, in the upper Delaware River basin, May–September 1963–67*—Con.

01-4321.60 Delaware River at Barryville, N.Y.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1964																															
May, max				14	14	15	16	17	18	18	18	18	18	17	17	18	18	18	19	20	19	21	21	22	22	21	21	19	19	22	22
min					13	11	14	15	16	17	16	16	16	16	15	15	17	17	17	19	17	19	18	19	20	19	19	18	17	16	18
June, max	20	20	19	18	19	19	18	18	19	22	22	25	24	26	25	23	21	23	23	22	25	25	24	24	23	23	24	24	25	25	----
min	18	17	17	17	16	17	17	18	18	19	19	19	19	20	23	19	18	18	21	19	22	24	22	23	22	22	22	23	24	23	----
July, max	24	24	25	24	24	24	23	23	22	23	24	22	24	23	24	24	25	26	28	30	28	24	27	27	23	22	27	24	27	27	26
min	23	23	23	23	24	23	22	22	22	21	22	22	21	21	22	22	22	23	26	28	24	23	24	23	22	22	22	23	24	22	24
August, max	25	26	25	25	26	25	23	24	24	23	22	24	24	23	21	21	21	21	21	21	19	20	21	22	22	22	23	23	22	23	24
min	24	25	25	24	24	23	23	23	23	22	22	22	23	21	20	20	20	20	21	19	19	19	20	21	22	22	21	21	21	22	23
September, max	23	23	22	22	23	23	22	22	23	23	25	25	22	19	18	18	18	19	19	18	18	18	19	19	19	17	17	17	17	16	----
min	23	22	21	22	22	22	22	22	22	22	23	22	19	18	18	17	17	18	18	17	17	18	18	19	17	17	17	16	16	16	----
1965																															
May, max	14	16	18	18	19	17	16	11	17	19	21	19	18	18	19	19	19	17	18	21	20	19	21	20	21	23	22	23	22	19	18
min	11	13	14	16	17	14	11	10	11	16	18	17	17	14	15	17	17	16	15	16	17	18	19	18	18	19	19	19	21	17	16
June, Max	18	18	19	19	20	22	24	25	26	26	26	26	23	21	19	19	19	20	21	23	24	26	26	25	24	24	25	26	27	26	----
min	17	16	16	16	17	18	21	22	21	24	23	22	19	19	17	17	18	18	18	19	21	21	21	22	21	20	21	21	23	23	----
July, max	25	26	24	26	25	26	23	24	26	24	23	24	25	27	27	26	26	25	24	23	24	22	23	24	26	26	24	23	22	21	23
min	21	21	22	22	23	23	22	21	23	23	21	19	21	23	23	22	22	23	22	20	19	20	19	21	24	23	21	21	20	18	19
August, max	21	21	20	21	23	24	26	25	25	26	25	25	24	25	26	27	26	27	25	24	23	22	22	23	23	22	23	23	22	18	17
min	20	19	19	18	21	21	22	23	23	23	23	22	22	21	23	24	24	23	24	22	21	20	20	21	21	21	21	22	18	17	17
September, max	18	19	19	20	20	21	22	20	20	23	21	20	18	18	18	20	20	21	22	23	24	25	25	24	21	19	17	16	15	15	----
min	17	17	18	19	19	18	19	19	19	19	20	18	17	17	17	18	18	18	19	20	21	21	22	21	19	17	16	14	14	15	----
1966																															
May, max	10	11	11	11	11	12	12	12	11	9	10	9	11	12	13	13	14	14	14	16	16	16	17	18	18	19	19	19	20	19	18
min	9	9	9	9	8	11	10	11	9	8	8	9	9	10	11	13	13	14	14	14	15	16	15	16	17	17	18	19	18	18	16
June, max	16	17	17	21	23	23	22	23	23	21	18	18	19	21	23	21	21	21	22	24	24	24	25	26	27	27	28	27	28	28	----
min	14	15	15	16	20	20	19	21	19	18	17	17	18	19	21	19	19	19	20	22	21	20	21	23	22	23	23	22	22	21	----
July, max	28	29	30	28	27	27	26	24	24	26	27	28	27	26	24	25	24	25	24	23	23	24	23	23	24	26	24	23	24	23	24
min	21	24	27	27	26	26	23	22	23	24	22	22	22	21	21	23	23	23	22	22	22	22	22	22	23	23	22	22	23	22	22
August, max	25	24	24	23	23	24	25	26	25	26	25	24	24	23	22	22	23	23	24	24	23	24	23	23	22	22	22	22	23	23	23
min	23	24	22	22	22	23	23	24	24	24	23	23	23	22	22	22	22	22	22	22	23	22	22	22	21	21	21	22	21	21	22
September, max	23	23	21	20	19	19	19	18	18	18	18	18	17	17	17	16	17	17	17	17	16	13	13	13	13	13	13	12	12	13	----
min	22	21	19	19	19	18	18	17	17	17	17	17	16	17	16	14	14	15	16	16	13	13	13	13	12	12	12	12	12	12	----
1967																															
May, max												9	10	10	10	10	12	13	13	13	12	12	13	13	12	14					
min												8	9	10	9	9	10	12	13	12	12	11	12	12	11	11					
June, max										26	24	26	26	24	24	24	25	25	23	21	22	22	22	22	22	22	21	22	21	19	----

min										24	23	23	21	23	22	20	21	23	21	19	19	21	21	21	22	21	20	20	19	19	
July, max	22	24	24	24	24	22	22	23	25	28	24	24	24	23	22	22	22	22	23	24	24	23	24	24	24	24	24	23	23	24	26
min	19	22	23	22	22	21	21	21	23	24	23	23	23	22	22	21	22	21	21	21	23	22	23	22	22	23	23	21	20	23	22
August, max	24	24	23	22	23	23	22																								
min	23	23	21	21	22	22	21	22																							
September, max																															
min																															

TABLE 5.—*Summary of monthly statistics of water-temperature data, in degrees Celsius, collected in the upper Delaware River basin, May–September 1963–67*

Date	Maximum	Mean maximum	Mean minimum	Minimum	Monthly mean	Maximum range	Mean range	Minimum range
1-4215. East Branch Delaware River at Hancock, N.Y.								
1964								
May	24	19.4	17.2	14	18	5	2.2	1
June								
July	29	26.1	23.3	16	24	4	2.8	1
August	19	16.7	15.0	13	15	3	1.7	0
September								
1965								
May	23	18.9	16.7	10	18	6	2.2	1
June	27	21.7	18.3	11	20	5	3.4	1
July	27	23.9	21.1	18	23	5	2.8	1
August	28	23.3	21.1	15	22	4	2.2	0
September	25	19.4	17.2	12	18	5	2.2	1
1966								
May	18	12.8	11.1	6	12	4	1.7	0
June	27	21.1	18.9	13	20	6	2.2	0
July	28	24.4	22.8	21	24	4	1.6	1
August	26	18.3	16.7	12	18	5	1.6	0
September	17	11.1	10.0	8	10	3	1.1	0
1967								
May								
June								
July								
August								
September	22	18.3	16.1	11	17	5	2.2	0
1-4250. West Branch Delaware River at Stilesville, N.Y.								
1963								
May	19	15.6	12.8	9	14	6	2.8	0
June	28	22.8	19.4	15	21	5	3.4	0
July	31	25.6	22.8	18	24	6	2.8	0
August	25	21.1	18.9	15	20	8	2.2	0
September	23	18.9	17.2	13	18	5	1.7	0
1964								
May	14	9.4	7.8	6	9	4	1.6	0
June	17	12.8	11.1	8	12	5	1.7	0
July	24	20.6	18.9	16	20	4	1.7	0
August	24	21.1	18.9	18	20	4	2.2	0
September	24	20.0	15.6	12	18	8	4.4	0
1965								
May	18	12.8	5.6	1	9	11	7.2	2
June	19	13.9	8.3	7	11	11	5.6	0
July	24	17.2	11.7	8	14	11	5.5	2
August	26	21.7	18.9	14	20	6	2.8	0
September	25	20.0	17.2	13	19	6	2.8	1
1966								
May	19	13.3	7.8	4	11	11	5.5	1
June	21	17.2	10.0	8	14	11	7.2	1
July	21	13.3	12.2	9	13	6	1.1	0
August	28	23.3	21.1	19	22	8	2.2	0
September	25	18.3	15.6	11	17	6	2.7	0
1967								
May	17	9.4	7.8	4	9	9	1.6	0
June	24	18.9	13	10	16	12	5.9	1
July	24	20.6	16	10	18	11	4.6	1
August	21	15.6	11.1	8	13	9	4.5	1
September	17	11.7	8.3	7	10	8	3.4	0

TABLE 5.—*Summary of monthly statistics of water-temperature data, in degrees Celsius, collected in the upper Delaware River basin, May–September 1963–67*—Con.

Date	Maximum	Mean maximum	Mean minimum	Minimum	Monthly mean	Maximum range	Mean range	Minimum range
1-4265. West Branch Delaware River at Hale Eddy, N.Y.								
1964								
May								
June	25	18.3	11.7	7	15	9	6.6	3
July	29	23.9	18.9	16	21	7	5.0	2
August	26	22.8	18.3	15	21	8	4.5	1
September	27	21.1	15.0	10	18	9	6.1	2
1965								
May	26	20.6	13.3	7	17	10	7.3	4
June	27	22.2	15.0	11	19	11	7.2	2
July	30	24.4	17.8	14	21	11	6.6	2
August	27	23.3	17.8	11	21	8	5.5	2
September	27	20.6	15.6	9	18	8	5.0	1
1966								
May								
June	28	23.3	16.1	12	19	10	7.2	3
July	25	18.9	13.3	10	20	10	5.6	3
August	27	25.0	20.6	19	17	8	4.4	1
September	26	18.9	15.0	9	12	6	3.9	1
1967								
May								
June	27	22.2	15.6	9	19	11	6.6	1
July	27	22.8	17.2	10	20	14	5.6	2
August	25	19.4	14.4	8	17	8	5.0	2
September	24	15.0	9.4	7	12	9	5.6	1
1-4272.07 Delaware River at Lordville, N.Y.								
1964								
May								
June								
July								
August								
September	19	16.1	13.9	11	15	3	2.2	1
1965								
May	23	17.8	15.0	9	16	6	2.8	1
June	26	21.1	18.3	12	20	5	2.8	0
July	27	23.3	21.1	19	22	4	2.2	1
August	28	22.8	20.6	15	22	5	2.2	0
September	24	18.9	17.2	12	18	4	1.7	0
1966								
May	19	13.3	11.7	7	12	4	1.6	0
June	28	21.7	19.4	14	21	5	1.3	0
July	26	20.6	18.9	17	20	4	1.7	0
August	24	20.6	18.9	16	20	2	1.7	0
September								
1967								
May								
June	26	22.2	20.6	15	21	4	1.6	0
July								
August								
September								

TABLE 5.—*Summary of monthly statistics of water-temperature data, in degrees Celsius, collected in the upper Delaware River basin, May–September 1963–67*

Date	Maximum	Mean maximum	Mean minimum	Minimum	Monthly mean	Maximum range	Mean range	Minimum range
1-4274.9 Delaware River at Callicoon, N.Y.								
1964								
May	24	19.4	17.2	13	18	4	2.2	1
June	26	22.2	19.4	16	21	4	2.8	1
July	30	25.6	23.9	21	25	3	1.7	0
August	24	21.7	20.0	16	21	6	1.7	0
September	23	18.9	17.8	13	18	3	1.1	0
1965								
May								
June	28	23.3	19.4	15	21	6	3.9	1
July								
August	29	23.9	21.7	16	23	4	2.2	1
Septemper	26	20.6	18.3	13	19	5	2.3	0
1966								
May	21	13.9	12.8	8	13	3	1.1	0
June	29	23.3	20.6	15	22	5	2.7	1
July	29	24.4	21.7	19	23	6	2.7	1
August	26	22.8	21.1	18	22	4	1.7	1
September	22	15.6	13.9	11	15	3	1.7	0
1967								
May								
June	28	22.8	20.6	14	22	4	2.2	0
July	27	23.9	21.7	18	23	4	2.2	1
August	26	21.7	20.0	17	21	3	1.7	0
September	23	18.3	15.6	10	17	8	2.7	1
1-4277.4 Delaware River at Narrowsburg, N.Y.								
1965								
May	25	20.0	16.7	11	18	5	3.3	1
June	28	23.3	19.4	15	21	6	3.9	1
July	28	25.0	22.2	20	24	5	2.8	1
August	29	24.4	21.7	16	23	4	2.7	1
September	26	20.6	18.3	13	19	5	2.3	0
1966								
May	20	13.3	12.2	7	13	3	1.1	0
June	29	23.3	20.6	15	22	4	2.7	1
July	31	25.0	22.8	21	24	6	2.2	0
August	26	22.8	21.7	19	22	3	1.1	0
September	24	16.1	14.4	9	15	4	1.7	0
1967								
May								
June	28	23.9	21.7	16	23	6	2.2	0
July	27	24.4	22.2	19	23	4	2.2	0
August								
September								
1-4285. Delaware River above the Lackawaxen River near Barryville, N.Y.								
1964								
May								
June	27	22.8	19.4	16	21	5	3.4	1
July	29	26.1	23.3	19	25	5	2.8	1
August	26	22.8	20.0	18	21	4	2.8	1
September	24	20.0	17.8	14	19	4	2.2	1
1965								
May	24	20.0	17.2	13	19	4	2.8	1
June	26	22.2	19.4	16	21	5	2.8	1
July	26	23.9	21.7	20	23	3	2.2	0
August	27	23.9	21.7	16	23	6	2.2	1
September	25	20.6	18.3	14	19	3	2.3	1

TABLE 5.—*Summary of monthly statistics of water-temperature data, in degrees Celsius, collected in the upper Delaware River basin, May–September 1963–67*—Con.

Date	Maximum	Mean maximum	Mean minimum	Minimum	Monthly mean	Maximum range	Mean range	Minimum range
1-4285. Delaware River above the Lakawaxen River near Barryville, N.Y.—Continued								
1966								
May								
June	28	22.8	20.6	16	22	6	2.2	1
July	29	26.1	23.3	20	25	4	2.7	1
August	26	24.4	21.7	19	23	4	2.7	1
September	26	18.9	16.7	12	18	4	2.2	1
1967								
May								
June	28	24.4	21.7	16	23	6	2.7	0
July	27	24.4	21.7	19	23	7	2.7	1
August	26	22.8	20.6	18	22	5	2.2	0
September	25	21.1	18.3	13	20	4	2.8	1
1-4321.6 Delaware River at Barryville, N.Y.								
1964								
May	22	18.9	16.7	11	18	6	2.2	1
June	26	22.2	20.0	16	21	6	2.2	0
July	30	25.0	22.8	21	24	5	2.2	0
August	26	22.8	21.7	19	22	2	1.1	0
September	25	20.0	19.4	16	20	3	0.6	0
1965								
May	23	18.9	16.1	10	18	6	2.8	1
June	27	22.8	20.0	16	21	5	2.8	1
July	27	24.4	21.1	18	23	5	3.3	1
August	27	23.3	21.1	17	22	4	2.3	0
September	25	20.0	18.3	14	19	4	1.7	0
1966								
May	20	13.9	12.8	8	13	2	1.1	0
June	28	22.8	19.4	14	21	7	3.4	1
July	30	25.6	22.8	21	24	7	2.8	1
August	26	23.9	22.2	21	23	2	1.7	0
September	23	16.7	15.6	12	16	3	1.1	0
1967								
May								
June								
July	28	23.3	22.2	19	23	4	1.1	0
August								
September								

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