A MODIFIED STREAMFLOW DATA PROGRAM FOR
NEW JERSEY by J.E. McCall and A.C. Lendo
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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

A MODIFIED STREAMFLOW DATA PROGRAM FOR NEW JERSEY

By

J. E. McCall and A. C. Lendo

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A MODIFIED STREAMFLOW DATA PROGRAM FOR NEW JERSEY

By J. E. McCall and A. C. Lendo

ABSTRACT

An evaluation of the streamflow data available in New Jersey was made to provide guidelines for planning future programs. This was part of a national evaluation program and, accordingly, national criteria and procedures were followed even though New Jersey is unique in its industrial development, population density and resultant water and environmental problems. The basic steps in the evaluation procedure were (1) definition of the long-term goals of the streamflow data program in quantitative form, (2) examination and analysis of all available data to determine which goals have already been met, and (3) consideration of alternative programs and techniques to meet the remaining objectives.

An evaluation was made first for the State as a whole; however, most of the accuracy goals could not be met and New Jersey was subsequently divided into two hydrologic areas, Coastal Plain and non-Coastal. It was found that many goals could be met by generalization of the natural flow data for gaged non-Coastal (north Jersey) basins by regression analysis. However, most of the goals were not met for the Coastal Plain (south Jersey) basins. Many small streams and essentially all larger streams in New Jersey are affected by regulation and diversion. A systems approach is necessary on streams of this type, using actual data on flow, regulation and diversion, but generalization based on regional characteristics is not practical for regulated streams.

The evaluation indicates that some changes and improvements could be made in the present data program. These would allow emphasis to be placed on attaining the goals that have not been met, especially in the coastal plain region where data are sparse and interflow between ground water and surface streams causes special complications. Such a modified streamflow data program is proposed and outlined for the future.

INTRODUCTION

General Features and Hydrology

New Jersey, one of the five Middle Atlantic States, has a land area of 7,509 square miles, including the offshore barrier beaches. According to the 1970 Census the population is about 7.5 million, an increase of 23 percent within the last 10 years. About 90 percent of this population live in urban and suburban areas. The climate is relatively mild and humid, owing to the proximity of the Atlantic Ocean, and precipitation averages about 45 inches annually.

The state is drained principally by streams flowing into the Atlantic Ocean and the Delaware River, with minor drainage into the Hudson River. The extent of underground drainage directly to the ocean and Delaware River is as yet unknown. Many streams are affected by tides in their lower reaches so that brackish water extends far inland.

The State may be divided into two major regions, based on difference in its geology, topography, and hydrology. The regions are separated by the Fall Line (fig. 2) which extends from Trenton to Perth Amboy, generally along or close to U.S. Highway 1. The area south of this Fall Line is termed the Atlantic Coastal Plain and is generally a flat sandy plain whose altitudes are less than 100 feet above sea level. Rocks of the Coastal Plain are geologically young and consist of unconsolidated clay, sands, and gravels. North of the Fall Line lies the Appalachian Highlands.

Topography in this area varies from the well-rounded hills of the Piedmont province in the southern section to the rough, mountainous, and well-wooded lands of the Valley and Ridge province in the northwest. Rocks in this area of the State are consolidated and geologically old.

History of Streamflow Program

The streamflow program of the U.S. Geological Survey in New Jersey has evolved through the years as the Federal and State interests in surface-water resources have increased and as funds for operating the stream-gaging station network have become available. There are now 85 daily discharge stations in the network plus nine stage-only or seasonal stations.

The earliest known collection of streamflow records in New Jersey was begun in 1877 on the Passaic River from Little Falls to Dundee Dam by private organizations, later reviewed and published (monthly totals) in the Annual Report of the State Geologist in 1894. The level of Lake Hopatcong was recorded daily beginning in 1887 by the Morris Canal and Banking Company. The City of Newark began records of flow on the Pequannock River at Macopin Intake Dam in 1892. Other stations were added slowly by various Federal, State, or City agencies reaching sixteen in number by 1904 but dropping back to eight in 1917.

In 1921 the State of New Jersey entered into a cooperative stream-gaging program with the U.S. Geological Survey, resulting in the establishment of 72 more daily-discharge stations by the beginning of World War II. The rapid expansion during the 1920's and 1930's was influenced by the need for data for planning, design, and operation of Wanaque and other proposed reservoirs to meet the geometrically increasing water demands of northeastern New Jersey and the Trenton-Camden region. The extended severe drought of the early 1930's and major floods of 1936 and 1938 also added impetus to this program to document the extremes of streamflow.

Thus, the streamflow measurement program grew in response to the need for information. However, about 1954 it became evident that the increasing costs for operation of gaging stations and the need for a greater variety of hydrologic information made it imperative that a more specific and systematic plan for data collection be devised. It was shown by statistical analyses and application of the then relatively new "information theory" (Langbein and Hardison, 1955) that less useful information per dollar spent was produced by continuing all gaging stations forever than could be produced through a flexible network concept. The plan that was developed and put into practice in 1957 by agreement between the U.S. Geological Survey and the New Jersey Division of Water Policy and Supply was the primary-secondary-water management and partial-record station network concept. That concept was described in detail (McCall, 1961), including a comparison of the stream-gaging networks in the various states of the U.S. and in other countries of the world, as well as changes in our national network in the first few years after 1957.

THE 1957 PLAN

Primary Stations

The 1957 plan designated 17 primary station sites well distributed geographically throughout the State. This included one main-stem primary (Delaware River at Trenton) and 16 areal primary stations. Main-stem primary stations were defined as those which were to be operated for a long term on a river with a large drainage area. The station was selected to monitor the changes with time of flow from a complex river system that may be influenced by changes in regulation or water use. Areal primary stations were defined as those operated for a long term on a network of smaller and essentially unregulated streams to define long-term representative characteristics of flow from selected major geologic and climatologic areas.

Secondary Stations

The 1957 plan recommended 29 secondary stations then existing and 7 more that had previously been discontinued after more than 10 years of operation. Secondary stations were defined as short-term satellite stations that were to be operated where complete streamflow information was needed, but only for periods long enough to relate the flow characteristics within a specified accuracy to those at nearby primary stations. From the relations thus established, long-term flow characteristics at the secondary station site were to be estimated from the long-term characteristics at one or more primary-station sites. Of the 36 secondary stations in the 1957 plan, most were in basins smaller than 40 square miles, 5 were in basins exceeding 100 sq mi in area. Only one (Delaware River at Belvidere) was a mainstem secondary station.

Water-Management Stations

In 1957 there were 34 stream-gaging stations in New Jersey that were designated water-management stations, a term that has since been changed to current-purpose stations. Current-purpose streamflow data are needed at many sites on a day-to-day basis for the management of water, for the assessment of current water availability, for the management of water quality, for the forecast of water hazards, and for the surveillance necessary to comply with legal requirements. This classification represents the need for information on the actual flow at any moment, or during any specific day, week, month, or year. Furthermore, these data are used currently for a particular purpose, and the interest is in flows as they occur, as well as in the historical record.

Streamflow data obtained for current use are of significant value. A current knowledge of the rate of flow and storage at different points in the system provides a basis for water-management decisions that govern the economic efficiency of the operation.

Current-purpose-data stations were considered separately in 1957 and again in this study because (1) justification can be related to specific needs, (2) the location of the stations and periods of operation are usually specified without regard to possible transfer value of the hydrologic data, and (3) the financing is usually provided by the user of the data.

Partial-Record Stations

The 1957 plan proposed to convert the secondary stations to partial-record stations after the secondary phase had reached the selected definition of monthly flow. Partial-record stations included both high-flow partial-record and low-flow partial-record stations, and were defined as stations to obtain, respectively, information on the annual peak discharge and base flow. This plan envisaged also the collection of peak-flow and low-flow data at many sites where continuous record gaging stations had never been operated.

Such low-flow data have been collected at 226 sites in New Jersey since 1958, nearly tripling by 1970 the number of streams and sites where reasonable estimates can be computed of mean flow, median flow, or the low flow that would be exceeded any specific percentage of the time. The latter type of estimate is being requested more and more frequently in recent years in connection with pollution abatement programs, often on small streams where gaging stations were not justified economically for water-supply or flood control studies.

A crest-stage partial-record network also was begun in the 1950's. Similar data from flood marks had been collected even earlier by the Passaic County Engineer's office and the Union County Park Commission. This was supplemented by crest-stage gage networks operated by the U.S. Geological Survey in cooperation with the Camden County Planning Board, the Bergen County Engineer's office, and the N.J. Division of Water Policy and Supply. The latter statewide cooperative program also includes the collection of low-flow data and the conversion of discontinued daily-discharge gaging stations to partial-

record stations. This cooperative program was further extended last year to include marking the high water elevations at many points along streams immediately following major flood events. Excluding the latter, crest-stage data are regularly recorded at some 88 sites in New Jersey, 63 of these by the U.S. Geological Survey.

CONCEPTS AND PROCEDURES USED IN THIS STUDY

The principal concept of this study is that streamflow information may be needed at any point on any stream in New Jersey and that the program must be designed to accomodate this need. It is conceded to be impractical, if not impossible, to physically collect data at all points. However, some information can be provided for any point by a combination of data collection and hydrologic studies that generalize the information obtained at gaging and partial-record station sites.

Another important concept is that the goals of the program, including accuracy goals, should be identified in quantitative form. This permits evaluation of existing data to determine which goals have been attained and how the program should be modified. This concept permits some improvement of the 1957 qualitative approach.

The procedures used in this study are those that have been adopted for standard use throughout the U.S. Geological Survey nationwide and are presented with reference to the general framework shown by table 1. Streamflow data are classified into four types; (1) data for current use, (2) data for planning and design, (3) data to define long-term trends (4) data on the stream environment. For the second type of data, streams are classified as natural or

regulated, and each of these classifications is further subdivided into principal or minor streams, with the separation of the two defined for New Jersey at a drainage area of 250 square miles (500 sq mi in most States).

In the initial phase of the study, program goals were established for each type of data. All available data were then examined and analyzed. This led to a comparison of the information now available with the goals that had been set and to consideration of the elements that should be included in the future program.

Current-Purpose Streamflow Data

The need for current streamflow data at many sites on a day-to-day basis (and sometimes on a "real-time" or within the last hour basis) was recognized in the 1957 Plan, described earlier under the heading "Water-Management Stations" and, in fact, as early as 1907 a New Jersey statute required the first such records. This part of the surface water investigations program is not subject to advance or theoretical design, but changes in response to specific needs for data in water management. Since 1957 telemetry equipment has been installed in 11 flood-warning or water-supply monitoring stations in New Jersey for instantaneous stage and discharge data transmission to the central offices. Similar telemetry is planned for installation at water-quality monitors on 8 or 9 streams in the next few months. The Water Supply Act of 1958 designated several gaging stations at which statutory minimum flows must be maintained by releases from reservoirs authorized by that Act. Many other stations are needed

Table 1. Framework for design of data collection program

Type of data	Current Purpose	Planning and Design ²				Long-term trends	Stream environment
		Natural Flow		Regulated Flow			
		Minor streams	Principal streams	Minor streams	Principal streams		
Goals	To provide current data on streamflow needed for day-by-day decisions on water management as required.	To provide information on statistical characteristics of flow at any site on any stream to the specified accuracy.				To provide a long-term data base of homogeneous records on natural-flow streams.	To describe the hydrologic environment of stream channels and drainage basins.
Drainage area limits	Full range	Less than 250 sq mi.	Greater than 250 sq mi.	Less than 250 sq mi.	Greater than 250sq mi.	Full range	Full range
Accuracy goal	As required	Equivalent to 10 years of record.	Equivalent to 25 years of record.	Equivalent to 10 years of record.	Equivalent to 25 years of record.	Highest obtainable	As required
Approach	Operate gaging stations as required to provide specific information needed.	Relate flow characteristics to drainage basin characteristics using data for gaged basins.	Operate gaging stations to obtain 25 years of record (or the equivalent by correlation) at a network of points on principal streams; interpolate between points.	Develop generalized relations that account for the effect of storage, diversion or regulation on natural flow characteristics.	Utilize analytical model of stream system with observed data as input to compute homogeneous records for both natural flow conditions and present conditions of development.	Operate a number of carefully selected gaging stations indefinitely.	Observe and publish information on stream environment.
Evaluate available data	Identify stations where data is used currently and code the specific use of data.	Develop relationship for each flow characteristic and compare standard error with accuracy goal. Evaluate sample.	Lay out network of points on principal streams and compare data available at these points with goal.	Appraise type of regulation, data available, and areas where relationships are needed.	Identify stream systems that should be studied using model approach and determine data requirements.	Select two stations in each WRC subregion to operate indefinitely for this purpose.	Evaluate information available in relation to goals.
Design future program	As needed to meet specific needs.	Identify goals that have not been attained. Consider alternate means of attaining goals. Identify elements of future program.				Operate selected stations forever.	Consider new kinds of data needed.

² May be varied with terrain and hydrologic conditions.

to document compliance with permits for storage or diversion issued by the State Water Policy Council and as a basis for levying charges for excess diversions. In fact, 75 percent of the existing stream-gaging stations in 1970 served one or more such management purposes and are classified as current-purpose data stations (see table A-1 in the appendix).

Data for Planning and Design

In general, the longer the stream-gaging record, the more reliable are the estimates of probable future occurrences. However, even with a long record, say 50-100 years or more, it is not possible to determine with great precision the probability of certain flow characteristics such as floods of a given magnitude, for example. The standard error of various streamflow parameters decreases with the years of available record, but at a decreasing rate; typical examples are shown in figure 1.

Figure 1.- Curve showing relation of standard error to length of record.

Designers and planners of water-related facilities increasingly utilize the statistical characteristics of streamflow rather than flow at specific times. The probability that the historical sequence of flow observed at a given site will occur again is remote, and predictions of future flows needed in design and planning must consider all probable flows and sequences of flow.

This information enables prediction of future streamflows, not in terms of specific events, but in terms of probability of occurrence over a span of years. For example, many bridges are designed on the basis of the flood that will be equaled or exceeded once in 50 years on the average; storage reservoirs can be designed on the basis of the probability of deficiency of storage for a given draft rate; the water available for irrigation, dilution of waste, or other purposes may be stated in terms of the mean flow or probability of flow magnitudes for periods of a year, season, month, week or day. In addition, there is a marked trend toward simulation of streamflow data based on the statistical characteristics of flow during the period of record such as the mean, standard deviation, and skewness coefficient. These kinds of statistics will be published for New Jersey streams shortly. The basin characteristics needed for simulation or correlation with flow statistics are given for existing gaging stations in table A-2 in the appendix of this report. As shown later, these may be used to compute the various flow statistics for ungaged natural streams in New Jersey. Such regional estimates may be very useful for general planning and preliminary designs of water projects. However, most large projects will warrant specific

data collection at the site and time should be allowed for this in early project planning.

A long record of streamflow is the best basis for defining statistical characteristics. Although it is not feasible to collect a long continuous record at every site where it will be needed, a number of such stations are required to provide information which can be transferred to ungaged sites, or to sites where a small amount of streamflow data is available.

For natural streams the transfer of streamflow information is done by regression methods, either by relating flow characteristics to basin characteristics such as drainage area, topography, and climate; by relating a short record to a long one; or by interpolating between gaged points on a stream channel. These methods are not applicable to the mainstem Delaware River and many smaller streams in New Jersey where the flow is affected by major regulation or diversion. Because different techniques are required to provide information on natural streams and regulated streams, the two are considered separately in program design.

For regulated streams a systems approach is necessary if meaningful information is to be provided. Operation of continuous gaging stations defines the regulated flow only at the sites of the stations and provides no firm basis for prediction of future flows in time or at other points on the regulated stream. The systems approach requires an analytical model and detailed information on the characteristics of the water management scheme that has been imposed on the stream. These characteristics may include stage-capacity curves of reservoirs,

operating-rule curves for release of water, diversions of water, and the channel geometry of the stream. The digital model thus developed would be somewhat similar to one used by water managers for daily decisions as to when to store or when to release water from a given reservoir to satisfy flow requirements downstream.

The required analytical models are simple in concept and will usually consist of water-budget equations and flow-storage equations. However, in many cases the use of the digital computer will be required for complex computations, or to handle efficiently large volumes of data. A computer program tailored to the individual system can be prepared, such as that used to compute natural flow at 228 sites in the Delaware River basin from 1923 to 1962 based on observed flow at 115 gaging stations and records of storage and diversion during the period.

Information on flow at some point or points on the stream is also necessary. Fortunately, many of the stations operated for the purpose of current data are on regulated streams and the records provide a base for the systems study.

For the purpose of setting accuracy goals, streams are further classified as minor streams and as principal streams. The intent is to use size of drainage area as an index of value of data. More costly developments on larger streams justify a higher accuracy goal for principal streams than for minor streams. The point of division between the two classes is a drainage area of 250 square miles.

Definition of flow characteristics of minor streams must be accomplished by some process of generalization, because of the large number of such streams in the State. For natural streams this can be

done by gaging at sample locations and relating the observed flow characteristics to basin characteristics to provide definition for ungaged streams.

Techniques of generalization normally cannot be used for principal streams because of higher accuracy requirements. The proposed approach here is to operate a network of gaging stations at selected locations on principal streams and, by interpolation or systems studies, to determine the flow characteristics at locations between stations. The procedure for defining the network of principal stream stations was as follows: (1) the first station on each stream was selected at the most upstream location where the drainage area was about 250 sq mi and (2) were selected in a downstream direction at points where the drainage area had approximately doubled (or more than doubled due to large tributaries entering the main stream).

Long-Term Streamflow Data

A long continuing series of consistent observations of streamflow is needed for two purposes: (1) analysis of the statistical structure of the hydrologic time series, and (2) as a reference or comparative base for noting changes in the regime at streams whose drainage basins or flows are developed for use.

Statistical statements on flow characteristics are based on the assumption that the data series is stationary in a statistical sense, and that the observed record is a representative sample of the population of flows. Long-term homogeneous streamflow data would provide a basis for checking these assumptions and for adjusting flow characteristics from short records to more nearly represent the characteristics of the flow population.

For these purposes the stations should be located on streams draining basins that have undergone no significant manmade changes, and that are expected to remain in a comparable condition in the future. The stations should be well distributed areally and should be located in basins having different physical characteristics. The stations would be operated indefinitely with the accuracy of gaging the highest that the state of the art permits.

Environmental Data

Stream discharge and water use are intimately related to the environment in which the water occurs. Environmental data include a wide variety of water-related information other than stream discharge. These data are useful in hydrologic studies and in planning, designing, and operating systems for controlling water or pollution. For example, data on the geometry of stream channels may be useful in appraising the use of a stream for recreation and in determining its capacity to assimilate waste; profiles of flood elevations are used in determining areas subject to inundation by floods; information on aquifer characteristics is valuable in conjunctive use of surface water and ground water.

GOALS OF THE NEW JERSEY STREAMFLOW PROGRAM

The objective of the streamflow data program is to provide information on flow at any point on any stream. Within this general objective, specific goals are set for each of the four types of data that represent the particular information that is needed. Acceptable accuracy levels are also specified because accuracy levels not only govern cost and techniques used in providing information, but also

provide a measure of specific goals. The uses of streamflow information in planning, design, and operation of water-related facilities and activities are illustrated in table 2. Note that in this context water-quality information is not included, although it is a significant and closely related program of growing importance in New Jersey.

Current-Purpose Streamflow Data

The program goal for this type of data is to provide the particular information needed at specific sites for current use. Accuracy goals at a given site depend on the requirements of a particular management system, and can be met by intensive observations or by more sophisticated instrumentation as needed and for as long a period as needed.

Data for Planning and Design

Streamflow records form the principal basis for the planning and design of water-related facilities. Designers and planners often utilize statistical characteristics of streamflow rather than the records of flow at specific times. The goal for this type of data is to define, within the given accuracy, the statistical flow characteristics listed in tables A-3 and A-4. The accuracy goals shown for flow characteristics in these tables are those equivalent to 10 years of record for minor streams.

The principal measure of the accuracy with which a particular streamflow characteristic can be determined is the standard error and is expressed in this report as a percentage of the average value of the characteristic. For flow characteristics (except standard

Table 2.-- Examples of surface-water information (excluding water-quality data) used in planning, design, and operation of water-related facilities and activities.

Problem	Sub-problem	Surface-water information needed
Flood forecasting		Current records of streamflow and stage; stage-discharge relation; flood-routing coefficients; precipitation; deterministic model.
Flood control	Levees	Flood-peak-frequency curve; channel cross sections and profiles.
	Reservoir design	Flood-volume-frequency relation (storage required-frequency relation); flood-routing coefficients.
	Reservoir operation	Same as flood forecasting, plus peak flow frequency for downstream uncontrolled areas; time of travel of flood wave (or routing coefficients).
	Zoning and insurance	Flood profiles; peak-stage frequency curves; velocity of overbank flow.
Highways	Bridge design	Peak-flow frequency; channel cross sections and profiles; stage-discharge relation.
	Grade design	Stage frequency and duration.
Municipal and industrial	Water supply	Low-flow frequency; storage requirements, peak-flow frequency; time of travel; synthetic streamflow records.
	Wastes, dilution and assimilation	Flow duration; low-flow frequency; time of travel; reaeration characteristics.
Recreation	Streams	Low-flow frequency; velocity; depth.
	Lakes	Peak-flow frequency; seepage; low-flow frequency; geometry and depths.

deviation of annual and monthly flows), the standard errors were determined from a theoretical relation of standard error to variability index and number of years of record. For standard deviations of annual and monthly flows, the standard errors, in percent, were determined from a relation of standard error to number of years of record.

Data to Define Long-Term Trends

The goal for this type of data is to operate indefinitely a small network of gaging stations on streams that are expected to be relatively free from manmade changes. Several such stations should be located in the State, preferably on streams that differ in physical characteristics.

Data on Stream Environment

Environmental data describe the basin and the stream channel in terms that will be valuable in planning the use of the stream for any purpose such as recreation, waste disposal, conjunctive surface water-ground-water supply, and in guarding against water hazards. The long-range goals for this type of data in New Jersey are given below.

1. Stream channel geometry including widths, depths, slopes, hydraulic roughness, bars and berms, and description of bed and bank material.
2. Profiles of flood elevations and areas subject to inundation by floods, including high water marks and major floods.
3. Data on land use including irrigated acreage, water storage, urban areas, cultivated acreage, and forested acreage.
4. Effects of man-made changes in the environment on streamflow and ecology.

5. Time of travel of water, solutes, and waste in channels.
6. Climatic characteristics, especially rainfall intensity and duration.
7. Data on location, extent, and characteristics of aquifers that are hydraulically connected to stream channels.
8. Basin characteristics: area, shape, land and stream slopes, and soils.
9. Tidal range and characteristics of estuaries and bays and data for coastal engineering.

EVALUATION OF EXISTING DATA IN NEW JERSEY

In this evaluation all available data are considered and analyzed in relation to program objectives. A separate evaluation is made for each of the four types of data.

Data for Current Use

Seventy-five percent of the gaging stations in New Jersey are operated to provide data for current use and must be maintained indefinitely. The gaging stations operated in New Jersey to satisfy the need for current data are identified in table A-1 in the appendix. The principal uses of the data for each station are also shown in that table. A summary of the number of stations serving the different principal current purposes is shown on the next page (many stations provide data for more than one use).

<u>Use of Data</u>	<u>Number of Stations</u>
1. Current assessment of water availability	3
2. Operation of water-related projects	11
3. Forecasting water hazards	22
4. Disposal of wastes	3
5. Management of water quality	14
6. Monitoring required by interstate compact, State statutes or grants	27
7. Research or special study	20

Data for Planning and Design

The statistical characteristics of streamflow can be defined by sample gaging, analytical methods of regionalization, systems studies, or any combination of the three. The following discussion of the evaluation of this type of data follows the framework shown in table 1.

Evaluation of the Natural-Flow Systems

The purpose of the evaluation is to determine how accurately the statistical characteristics that are listed as goals can be defined by regionalization of that data now available.

The most effective way now known for defining statistical streamflow characteristics on a broad scale is to relate the streamflow characteristics to basin characteristics in equations developed by use of multiple-regression techniques applied to past data.

Once the equation and its constants are defined, streamflow characteristics for a specific site in a given basin can be computed by substituting the appropriate values of the hydrologic variables in

the formulas.

Streamflow records for 61 stations in New Jersey, 1 in New York and 15 stations in Delaware were used in the analysis. These stations had 10 or more years of mostly unregulated flow, or flow that could be adjusted to natural conditions. Both minor and principal streams are included. Records were not adjusted to a base period. Because of some regulation and/or diversion, not all flow characteristics were defined for each record. At some stations regulation and/or diversion materially affected low flows but insignificantly affected peaks. At a few stations, only mean annual flows, adjusted for storage, were used.

Figures 1 and 2 show the locations of continuous-record stations on natural flow and regulated streams in New Jersey, respectively. Streamflows at stations shown on figure 1 have not been significantly affected by regulation or diversion, as known in June 1970. For stations shown on figure 2, streamflow conditions are also as of June 1970. However, there were long periods of natural flow records for some of that stations shown on figure 2 which were utilized for this evaluation. Table A-5 in the appendix lists the unregulated and regulated periods of record for active and discontinued stations.

Excluding the Delaware River stations, streamflow records were available for only 5 stations with drainage areas over 200 sq mi. These stations are in the Passaic and Raritan River basins and they are listed in a later section on page 28 of this report. Only the high flow records for 4 out of the 5 stations (excluding the

Figure 2.-- Map of New Jersey showing locations of continuous-record stations on natural flow streams.

Figure 3.-- Map of New Jersey showing locations of continuous-record stations on regulated streams.

Pompton Plains station) were utilized for the natural flow analysis. The flow at the Delaware River stations is significantly affected by regulation and diversion at the present time. However, flow during many early years of the long records were not too significantly affected, particularly at the farthest downstream stations. The Delaware River streamflow data were utilized in the non-Coastal Plain area analyses.

A statewide evaluation, utilizing the data for the 61 New Jersey and 1 New York natural-flow stations, was made but it was found that most of the accuracy goals could not be met with only a single region and single regression for the whole State. New Jersey was finally divided into two major hydrologic areas, Coastal Plain and non-Coastal Plain, with U.S. Route 1 as the approximate division line. This division resulted in improved definition of streamflow variables. Data for 21 New Jersey and 15 State of Delaware stations were added to the data matrix so as to increase the sample size and provide a greater range of basin and streamflow characteristics.

Streamflow characteristics

The following streamflow characteristics defined at gaging stations were used in the regression analyses:

1. Flood-peak characteristics are represented by discharges from the annual flood-frequency curve at recurrence intervals of 2, 5, 10, 25, 50, and 100 years. These peak flows are

denoted as Q_2 , Q_5 , etc. The frequency curves were prepared as described by the Water Resources Council (1967).

2. Flood-volume characteristics represent the annual highest average flow for 7-day periods at recurrence intervals of 2, 10, and 50 years. These characteristics are noted symbolically as $V_{7,2}$, $V_{7,10}$ and $V_{7,50}$. They were determined from frequency curves prepared as described by the Water Resources Council (1967).
3. Low-flow characteristics are the annual minimum 7-day mean flows at recurrence intervals of 2, 10, and 20 years ($M_{7,2}$, $M_{7,10}$, and $M_{7,20}$). They are determined from frequency curves prepared as described by the Water Resources Council (1967), except for stations with some zero values when they were determined from graphical frequency curves.
4. Mean-flow characteristics are described by the mean of the annual means, Q_a , and by the means of record for each calendar month, q_n , where the subscript refers to the numerical order of the month beginning with January as 1.
5. Flow-variability characteristics are represented by the standard deviations of the annual and monthly means. The symbols used are, respectively, SD_a and SD_n , where subscript n refers to the numerical order of months with January as 1.

Drainage-basin characteristics

Drainage-basin characteristics defined for this study are:

1. Drainage area (A), in square miles, as shown in the latest Geological Survey streamflow reports.
2. Main channel slope (S), in feet per mile, is the average slope between points 10 percent and 85 percent of the distance from the gaging site to the basin divide (main channel length - Benson, 1962).
3. Main channel length (L), in miles, is the length of the main channel between the gaging station and the basin divide measured along the channel which drains the largest basin.
4. Area of lakes, ponds, and swamps (St), in percent of drainage area, (plus one percent) which was measured by planimetering on U.S. Geological Survey 7.5 minute series (topographic) maps.
5. Mean basin elevation (E), in 1,000 feet above mean sea level, measured on U.S. Geological Survey topographic maps by a transparent overlay grid sampling method.
6. Forested area (F), in percent of drainage area, and increased by one percent. This was measured by grid-sampling method from U.S. Geological Survey topographic maps having a green overprint which indicates forest cover.

7. Mean annual precipitation (P), in inches. This parameter was determined from an isophyetal map prepared in collaboration with the U.S. Weather Bureau and published in U.S. Geological Survey Hydrologic Investigation Atlas HA-11.
8. Precipitation intensity ($I_{24, 2}$) expected in 24 hours once each 2 years, in inches. This characteristic was estimated from U.S. Weather Bureau Technical Paper No. 29.
9. Mean minimum January temperatures (T), in degrees F. These values were determined from the New Jersey publication of U.S. Weather Bureau series "Climates of the States"
10. Soils index (Si), is a coefficient expressing the hydrologic effects of soil, land use and cover. These values were furnished by the U.S. Soil Conservation Service.

Values of the above basin characteristics for each of the 62 New Jersey and 15 Delaware gaging stations used in the analysis are listed in table A-2. Other characteristics are being examined and may be added later especially those which are found to be significant from studies of the effect of urbanization on streamflow now in progress.

Regression analysis

The next step was to relate each of the streamflow characteristics to basin (topographic or climatic) characteristics in equations developed by using multiple regression techniques. The equation has the form $Y = a + b_1 S + b_2 L + b_3$ ----, where Y is a statistical streamflow

characteristics; A, S, and L are topographic or climatic characteristics; a is the regression constant; and b_1 , b_2 , and b_3 are coefficients obtained by regression. This method was described by Benson (1962). In this study, all of the 10 basin characteristics were used initially in each regression. The computer calculated the regression equation, the standard error of estimate, and the significance of each basin parameter. Automatically, then, the computer repeated the calculations, omitting the least significant basin parameter in each calculation until only the most significant parameter remained. After relations for a given streamflow characteristic had all been computed, the entire computation process was repeated using streamflow characteristic along with the same set of basin characteristics.

Table 3 illustrates the output of the regional regression analyses of mean annual flow in the non-Coastal Plain area of New Jersey. On the basis of the regression analyses, the equation for determining mean annual discharge at ungaged sites on natural streams in this area, which includes all statistically significant variables, is

$$Q_a = 0.818A^{1.05}S^{0.10}(St + 1.0)^{0.091}$$

where Q_a is mean annual discharge, in cubic feet per second; A is drainage area, in square miles; S is slope in feet per mile; and St is area of lakes, ponds and swamps, in percent of drainage area. This analysis showed drainage area to be most significant; storage in lakes, ponds and swamps of second significance; slope of third significance; etc. for estimating mean annual discharge. Conversely,

Table 3.--Summary of regression analyses of mean annual flow for non-Coastal area.

Dependent variable	Regression coefficients for independent variables										Regression constant	Standard error of estimate	
	Area	Slope	Length	Storage	Elevation	Forest	Precipitation	Precipitation Intensity	Minimum January Temperature	Soil		Percent	Percent change ^a
Mean annual flow	^b 1.02	0.046	0.025	^c 0.065	0.13	0.14	0.057	-0.66	^c 0.67	-0.027	0.176	8.9	-
	^b 1.01	.049	.032	^c .067	.12	.12	.049	-.68	^c .65	-	.198	8.8	-0.1
	^b 1.02	.053	.031	^c .068	.12	.12	-	-.67	^c .66	-	.216	8.6	-.2
	^b 1.03	.053	-	^c .066	.12	.12	-	-.64	^c .66	-	.211	8.6	0
	^b 1.05	^c .066	-	^c .061	.085	.13	-	-	.45	-	.154	8.7	+ .1
	^b 1.06	^b .084	-	^c .064	-	^c .15	-	-	.26	-	.218	8.9	+ .2
	^b 1.04	^b .079	-	^b .072	-	.11	-	-	-	-	.612	8.9	0
	^b 1.05	^b .10	-	^b .091	-	-	-	-	-	-	.818	9.4	+ .5
	^b 1.01	-	-	^c .065	-	-	-	-	-	-	1.38	11.1	+1.7
	^b 1.01	-	-	-	-	-	-	-	-	-	1.49	14.8	+3.7

a Percent change when least significant variables are dropped, as indicated by dashed line in column.

b Significant at 1-percent level.

c Significant at 5-percent level.

the least significant were soils index, annual precipitation, channel length, etc. for estimating mean annual discharge. The significant basin characteristics differed for various streamflow characteristics (see tables A-3 and A-4).

Thirty-eight streamflow characteristics were used in the analyses. However, meaningful equations were not derived for any of the low-flow characteristics in either region or for the 100-year flood peak for the Coastal Plain area. The results of the regression analysis for the streamflow characteristics are shown in tables A-3 (non-Coastal) and A-4 (Coastal Plain). Equations that relate each flow characteristic to significant basin characteristics are defined. The standard error of estimate for each equation and for comparison, the accuracy goals (10-year and 25-year standard error) of each flow characteristic are also given. A detailed discussion of this comparison will be deferred to a later section of this report.

Principal streams

The goal of this category is to define the natural flow of principal streams (> 250 square miles) in New Jersey. Because principal streams are considered of more importance to the economy, accuracy requirements are set higher than that for minor streams. Requirements are stipulated to be the equivalent of that obtained from an actual record of 25 years.

There are no natural flow streams larger than 250 square miles in New Jersey, and all of the principal streams are considered in the evaluation of the regulated-flow systems.

Evaluation of the Regulated-Flow Systems

The goals for regulated streams are more difficult to attain because the technique of regionalization does not apply, the characteristics are not necessarily stationary in time, and a meaningful correlation seldom exists between flows at two sites if at least one of the flows is regulated. A systems approach may be used to define the characteristics of regulated streamflow under different patterns of regulation, or under the condition of natural flow. Systems studies for all of the regulated-stream systems in New Jersey will require a major effort. The regulated flow stations are shown plotted on fig. 2 and are identified in table A-5.

In addition to the many gaging sites in the Passaic, Raritan and Delaware River basins, there are many sites on minor streams where the measured flow is not natural. Regulation by reservoirs is a factor at a few of these minor stream sites, however, most often the factors are diversions from surface water and/or well fields, return of treated waste waters, or effects of urbanization.

Determination of streamflow characteristics for regulated streams will involve adjusting the recorded flows for effect of regulation, diversion and urbanization. Reservoir gages to determine the contents of all major reservoirs are in operation and, for most of these reservoir sites, inflow or outflow records are being collected. Diversion for all large water supply systems are currently recorded but the location and flow rates for many intake pipes and waste water effluent pipes along the channel are poorly documented. In the adjustment for diversion, a more complex

problem is the adjustment for partial or indirect diversion from well fields, which are placed on the banks of some streams. Urbanization is a factor affecting not only flood runoff, but also low flows because of street washing, reduced ground water infiltration, return of untreated and treated waste waters, and similar practices. Not all of these man-made effects exist or, if so, may be insignificant in many basins but they need to be investigated and taken into account for certain studies.

The Trenton district has completed a project wherein natural flow monthly and annual mean discharges for the period 1923-62 were computed by correlation or adjustment for storage, diversion and evaporation at many sites in the Delaware River basin.

Data on Stream Environment

Many environmental factors were determined for the drainage basins for the present study, particularly basin characteristics (see fig. 2 and table A-2 of the appendix).

Nine flood-plain inundation studies have been completed for reaches on the Raritan, Millstone and Delaware Rivers, and Stony and Beden Brooks. A flood-plain inundation study on Crosswicks Creek is in progress.

Flood plains have been outlined on 47 topographic quadrangle maps and flood profiles defined for selected streams. Channel surveys have been made at many sites in connection with indirect determinations of peak flows for unusual floods. Channel geometry has been determined at more than 100 gaging stations and in a number of reaches where time-of-travel studies have been conducted.

DISCUSSION OF THE EVALUATION

Of the four data categories used in this study, only one, data for planning and designing of water projects, is clearly subject to design. The requirements for other types of data are established in response to specific needs, or are defined by hydrologic judgment.

The evaluation of available streamflow data by regression analysis was based on data from 77 continuous-record gaging stations. Records from both minor streams with natural flow and principal streams with only moderate regulation were included. The conclusions and implications drawn from the results, based on standard errors shown in tables A-3 and A-4 are:

1. For natural flows, in the non-Coastal region use of the regression equations was found to provide estimates of mean annual discharge, standard deviation of annual discharge, mean monthly discharge, and standard deviation of monthly discharge within the accuracy objectives. Therefore, no additional daily discharge data are required to define these mean flow characteristics on minor streams in northern New Jersey. Data collection on flood peak discharge and annual minimum flow should be continued, however, as the standard error of the regression results for both maximum and minimum flows were higher than the goals.

2. Accuracy objectives in the Coastal Plain of New Jersey

were met only for estimates of standard deviation of annual discharge and some of the standard deviations of monthly discharge. Therefore, all useful daily discharge records in this region should be continued. Also additional short-term continuous record and partial-record stations should be added as quickly as possible, with emphasis on low-flow and peak flow data but including also mean flow records. A positive effort should be made to integrate streamflow and groundwater studies in this region to identify the quantity and locations of underground flow from one stream basin to another or to the ocean. The effect of increased future groundwater utilization on this deep percolation between basins should be evaluated.

3. Low-flow characteristics at ungaged sites on natural-

flow streams, (or regulated streams) minor or principal, cannot be estimated accurately by regression. Thus, accurate estimates of low-flow characteristics at a site will require at least a few measurements of low flow there correlated with concurrent flows at a suitable continuous-record index station where similar hydrologic conditions prevail.

4. Regression equations were defined for streamflow characteristics for all sizes of drainage areas, including those of less than 10 square miles. However, because of small sample size and great variability in the similar basins the regression equations should be used with great care for determining mean flows and flood discharges from drainage areas of less than 10 square miles. Continuous-record or partial-record stations should be operated to define and confirm the streamflow characteristics for small drainage areas.
5. Likewise, regression equations should not be used, in general, for natural-flow streams in New Jersey with drainage areas larger than 130 square miles. The very few streams larger than that, in the State, have all been developed for water supply, sewage disposal, flood control and recreational use or other purposes.
6. The gaging-station network was found to be of sufficient density in northern New Jersey to meet general requirements except estimates of flood peaks and minimum flows. In the Coastal Plain the network was not sufficiently developed to supply adequate answers on average flows (except the annual average), let alone the extremes of flow.

THE PROPOSED PROGRAM

This report has concentrated on the methods of obtaining information for determining the statistical characteristics of unregulated streamflow and on the accuracy goals for such information. Viewed solely from the standpoint of information for defining the statistical characteristics of unregulated flow the stream-gaging program would be subject to radical changes. The biggest changes would be to discontinue daily-discharge stations at many places in northern New Jersey and put the funds and manpower thus released into an expanded program of crest-stage gages or low-flow measurements. Many of these changes, however, are prevented by needs for flow data for statutory or other purposes at particular sites. Most of the stations are needed to provide current information for use in management of the water resources. Records of streamflow are needed at water quality stations and for forecasting and other special needs. Nevertheless, a few stations in the north were identified for conversion to maximum and minimum flow stations and specific sites were selected for additional stations on the Coastal Plain.

For the optimum program, a balance must be maintained between data collection and data analysis, as continuous interaction between the two is needed, not only to gain a better understanding of the hydrologic system, but also to guide future evaluation of that program in meeting ever-changing needs and in adapting to changing technology.

Data Collection

Data for current use

Operation of the 64 stations, identified as presently meeting the needs for current-purpose data (table A-1), should be continued. The changing needs will be assessed continuously, and the data-collection network may be modified later by adding or discontinuing stations if and when needs change for current-purpose data.

The Raritan River Basin has been tentatively selected for early systems studies of regulated flow. Flow regulation began at Spruce Run Reservoir in September 1963. Round Valley Reservoir was completed next and diversion to this reservoir of flood flows from the South Branch Raritan River was begun in February 1966. Future plans call for regulation of the North Branch Raritan and Millstone River flows. Eventually all reservoirs in the basin will need to be operated in a coordinated system of "real-time" data collection, transmission to a central point and use in an automatic computer-controlled system for balancing releases with needs at different points in the basin.

Data for planning and design

Some principal objectives have been attained in the non-Coastal areas; however, continued operation of certain stations to obtain either continuous-record or partial-record data is indicated,

especially for basins smaller than 10 sq miles in the Coastal Plain area are needed for generalization studies. Such studies will be continued to determine if other basin characteristics may be significant and utilized in meeting the accuracy goals that have not been attained thus far. One station, to fill an information gap, is proposed for establishment on Clove Brook in northwestern New Jersey, and stations are proposed on ten streams in the Coastal Plain to increase range of basin and streamflow characteristics sampled. These stations (numbers not assigned), given in table A-1 and plotted on figure 1, are as follows:

Clove Brook at Sussex

North Branch Metedeconk River at Lakewood

Westecunk Creek at Stafford Forge

Oswego River near Brookville

West Branch Wading River near Harrisville

East Branch Bass River near New Gretna

South River near Mays Landing

Scotland Run at Malaga

Manumuskin River near Manumuskin

Stow Creek at Jericho

South Branch Big Timber Creek at Blackwood

The stations now in operation were also reviewed with State officials and four stations are recommended for discontinuance and conversion to partial-record stations:

Pascack Brook at Westwood (regulated flow, minor stream)

Baldwin Creek at Baldwin Lake near Pennington (natural flow, minor stream)

Delaware River at Riegelsville (regulated flow, principal stream)

Alloway Creek at Alloway (natural flow, minor stream)

Low-flow characteristics at ungaged sites cannot be estimated by regression methods. However, information on low-flow characteristics has been collected at about 226 sites throughout the State, and this, together with such information available from the regular stream-gaging network, provides a data base from which, by interpolation, reasonable estimates of low-flow characteristics can be made for about 300 of the most important streams. Additional data are needed at 105 of the presently operated low-flow partial-record sites to sample the full range of low flow; these 105 sites will be continued in operation through 1971. Other sites will be added as needed until all streams with potential water problems have been sampled during base flow. Low-flow characteristics may be defined at otherwise ungaged sites by correlating a few low-flow measurements at the site with concurrent flow data at a suitable continuous-record index station where similar hydrologic conditions prevail.

Regression equations are given for flood-volume and flood-peak estimates; however, the accuracies are not within the accuracy goals. To meet these goals it is not only necessary to continue the present continuous-record and partial-record crest-stage stations but to monitor a greater range of basin characteristics. Although the objective of this program included only the 50-year flood, flood-peak characteristics at recurrence intervals of 100 years are often estimated for flood insurance, flood zoning and project design. For this reason it is desirable to continue collecting flood-peak data indefinitely. For each streamflow station subject to discontinuance, consideration should be given to the continued collection of peak-flow data at the site.

Data to define long-term trends in streamflow

Four stations have been designated as long-term-trend stations and should be operated indefinitely to meet the needs for this type of data. These were selected mainly because they have been least affected to date by works of man and seem likely to continue thus in the foreseeable future. The drainage area and period of record are shown for each station.

<u>Station number</u>	<u>Station name</u>	<u>Drainage area (sq mi)</u>	<u>Period of record</u>
3860	West Brook near Wanaque	11.8	1934-
4400	Flat Brook near Flatbrookville	65.1	1923-
4665	McDonalds Branch in Lebanon State Forest (benchmark station)	2.31	1953-
4825	Salem River at Woodstown	14.6	1940-

Data on stream environment

It is proposed to strengthen this part of the program as rapidly as funds and manpower will permit. To some extent collection of related environmental data has suffered in the past due to over-concentration on daily-discharge gaging stations. The goals for this part of the program were listed earlier on p. 17 and are incorporated herewith in their entirety in the proposed future program. Immediate emphasis is recommended on studies of urbanization effects on flood peaks.

Summary

Table A-1 summarizes the proposed program for data-collection at continuous gaging stations. The table includes all streamflow stations now in operation and those to be established for the proposed program. Each station is identified as to type of data and recommendations are made as to whether the station should be included in the proposed network or whether it has met the objective for which it was operated and could be discontinued. Data collected at most current-purpose gaging stations may also be used for planning and design. The locations of gaging stations included in the proposed program are shown on figures 1 and 2.

Data Analysis

The streamflow-data network operated through the years supplies a base for analyses and reports. Some aspects of data analyses are of a continuing nature and help to guide and insure the quality of the data collection effort. Other studies compile, analyze or interpret the basic data in ways to make them more readily and

efficiently useful to the State, Federal and local officials, engineers, conservationists, planners, students, research scientists, and others concerned in one way or another with water resources.

The proposed program of data analyses for New Jersey streams may be classed in two phases--those based on data collection to date, and those for which additional data will be required.

Data analyses and appropriate reports should be scheduled for completion during the next 2 years on the following:

1. Statistics of mean annual and mean monthly flows--report now ready for printing.
2. Low-flow frequency of New Jersey streams--directed specifically to the most complete analysis now possible on the extreme low-flows during drought periods.
3. Flood-volume frequency based on analysis of annual maximum average flows for selected periods of time.
4. Magnitude and frequency of peak flows--an update of the the report, "Magnitude and Frequency of Floods in New Jersey," to include the records of the intervening 10 or 11 years and hopefully, a better technique for use in urban areas.

Utilizing available data to the extent possible, but depending primarily on the collection of additional data specifically required, the following analyses and reports should be initiated as a part of the proposed streamflow data program:

1. Time of travel and dispersion of solutes in selected streams in New Jersey, giving first priority to the

reach of the Delaware River in the State.

2. Regulated-streams systems analysis, giving first priority to the Raritan River basin.
3. The Mullica River stream-aquifer flow system.
4. Evaluation of the effects of proposed regional trunk sewers on streamflow.
5. Special reports on major floods as they occur in the State.
6. Gains and losses of flow of selected streams, especially in the Coastal Plain.
7. Frequency of floods in small urban and suburban areas and improved data for storm sewer design.
8. The effects of small reservoirs, ponds and swamps on streams-flow characteristics.
9. Comprehensive urban hydrology studies including all environmental factors.

These are only a few of the data analyses and hydrologic studies that could be made. Changing needs for streamflow information and changes in technology in water-related fields must be continually evaluated in light of the data analyses that should be generated under the streamflow data program for New Jersey.

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APPENDIX A

Table A-1.--Purpose of gaging stations in operation and proposed for the network.

Column 1: B, benchmark or long-term change station.

Column 2: C, current purpose station.

Column 3-5: Purpose for which current-purpose station is operated; 1, accounting; 2, operation; 3, forecasting; 4, disposal; 5, water quality; 6, compact or legal; 7, research or special study.

Column 6: H, hydrologic station; (), proposed station; R, station required for systems analysis of a regulated stream; U, station not recommended for inclusion in future program.

Column 7: Effect of regulation or diversion on low flow and monthly flow; blank, no appreciable effect; 1, no appreciable effect on daily flow (diurnal fluctuation only); 2, monthly flow not appreciably affected by diversion or affected not over 10 percent by regulation; 3, monthly flow

affected, but published data available to adjust to natural flow conditions with an error of less than 10 percent; 4, monthly flow affected by more than 10 percent and data not available to adjust to natural conditions with an error of less than 10 percent.

Column 8: Effect of regulation on peak flow: blank, no appreciable effect; 1, annual peak flow affected by less than 10 percent; 2, annual peak flow affected by more than 10 percent.

Column 9: Financing of station: 1, U.S. Geological Survey; 2, U.S. Geological Survey and State of New Jersey; 3, other federal agency; 4, combination of 1 and 2; 5, combination of 1 and 3; 6, combination of 2 and 3; 7, combination of 1, 2, and 3.

Station number	Station name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
3770.	Clove Br. at Sussex	-	-	-	-	-	(E)	-	-	-
3775.	Hackensack R. at Rivervale	-	C	2	-	-	-	3	2	2
3785.	Pascack Br. at Westwood	-	-	-	-	-	U	-	-	-
3786.9	Hackensack R. at New Milford	-	C	6	-	-	-	4	2	2
	Passaic R. nr Bernardsville	-	-	-	-	-	H	-	-	2
3790.	Passaic R. nr Millington	-	C	6	-	-	-	3	-	2
3795.	Passaic R. nr Chatham	-	C	6	3	-	-	3	-	6
3796.3	Russia Br. trib. at Milton	-	-	-	-	-	H	2	1	2
3805.	Rockaway R. above reservoir at Boonton	-	C	2	-	-	-	3	1	2
3810.	Rockaway R. below reservoir, at Boonton	-	C	6	4	3	-	3	2	2
3815.	Whippany R. at Morristown	-	C	4	-	-	-	-	-	2
3825.	Pequannock R. at Macopin intake dam	-	C	6	3	-	-	4	2	2
3835.	Wanaque R. at Awosting	-	C	6	-	-	-	3	2	2
3840.	Wanaque R. at Monks	-	C	2	-	-	-	3	2	2
3845.	Ringwood Cr. nr Wanaque	-	C	2	-	-	-	-	-	2
3860.	West Br. nr Wanaque	B	-	-	-	-	H	-	-	2
3870.	Wanaque R. at Wanaque	-	C	6	3	-	-	4	2	2
3875.	Ramapo R. nr Mahwah	-	C	3	-	-	-	1	-	2
3880.	Ramapo R. at Pompton Lakes	-	C	6	3	-	-	4	1	2
3885.	Pompton R. at Pompton Plains	-	C	6	3	-	-	4	2	6
3895.	Passaic R. at Little Falls	-	C	6	3	4	-	4	2	2
3905.	Saddle R. at Ridgewood	-	C	7	-	-	-	1	-	2
3910.	Hohokus Br. at Hohokus	-	C	7	-	-	-	-	-	2
3915.	Saddle R. at Lodi	-	C	6	3	-	-	3	-	2
3935.	Elizabeth R. at Elizabeth	-	C	7	-	-	-	4	-	2
3945.	Rahway R. nr Springfield	-	C	7	-	-	-	4	1	2
3950.	Rahway R. at Rahway	-	C	6	-	-	-	4	1	2
3960.	Robinsons Branch Rahway R. at Rahway	-	C	6	-	-	-	4	2	2
3965.	So. Br. Raritan R. nr High Bridge	-	C	1	2	5	R	-	-	4
3968.	Spruce Run at Clinton	-	C	6	-	-	R	3	2	2
3970.	So. Br. Raritan R. at Stanton	-	C	6	5	3	R	4	2	2
3980.	Neshanic R. at Reaville	-	-	-	-	-	R	-	-	2
3985.	No. Br. Raritan R. nr Far Hills	-	C	5	-	-	R	-	1	2
3995.	Lamington R. nr Pottersville	-	-	-	-	-	R	-	-	2
4000.	No. Br. Raritan R. nr Raritan	-	C	2	5	3	R	-	-	2

Table A-1.--Purpose of gaging stations in operation and proposed for the network--continued.

Station number	Station name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
4005.	Raritan R. at Manville	-	C	6	3	5	R	3	1	2
4007.3	Millstone R. at Plainsboro	-	-	-	-	-	H	-	-	2
4009.32	Baldwin Cr. at Baldwin Lake	-	-	-	-	-	U	-	-	-
4009.53	Roney Branch nr Pennington	-	C	7	-	-	-	-	-	2
4010.	Stony Br. at Princeton	-	-	-	-	-	R	-	1	2
4020.	Millstone R. at Blackwells Mills	-	C	2	3	5	R	4	1	2
4025.9	Royce Br. trib. at Frankfort	-	C	7	-	-	-	-	-	2
4026.	Royce Br. trib. nr Belle Mead	-	C	7	-	-	-	-	-	2
4030.6	Raritan R. at Bound Brook	-	C	6	3	5	R	3	1	2
4035.	Green Br. at Plainfield	-	C	7	-	-	-	4	1	2
4050.	Lawrence Br. at Farrington Dam	-	C	6	-	-	-	3	2	2
4054.	Manalapan Br. at Spotswood	-	C	2	-	-	-	-	2	2
4055.	South River at Old Bridge	-	C	6	-	-	-	4	1	2
4075.	Swimming R. nr Red Bank	-	C	6	-	-	-	3	2	2
4077.05	Shark R. nr Neptune City	-	C	6	-	-	-	-	-	2
4077.6	Jumping Br. nr Neptune City	-	C	6	-	-	-	-	-	2
4080.	Manasquan R. at Squankum	-	C	5	7	-	-	-	-	2
	North Branch Metedeconk R. at Lakewood	-	-	-	-	-	(H)	-	-	-
4085.	Toms R. nr Toms River	-	C	5	-	-	-	-	-	2
4090.95	Oyster Cr. nr Brookville	-	-	-	-	-	H	-	-	2
4094.	Mullica R. nr Batsto	-	-	-	-	-	H	-	1	2
4095.	Batsto R. at Batsto	-	C	7	-	-	-	1	1	2
	Westecunk Cr. at Stafford Forge	-	-	-	-	-	(H)	-	-	-
	Oswego R. nr Brookville	-	-	-	-	-	(H)	-	-	-
	West Branch Wading R. nr Harrisville	-	-	-	-	-	(H)	-	-	-
4100.	Oswego R. at Harrisville	-	C	7	-	-	-	-	1	2
	East Branch Bass R. nr New Gretna	-	-	-	-	-	(H)	-	-	-
4105.	Absecon Cr. at Absecon	-	C	6	-	-	-	4	2	2
4110.	Great Egg Harbor R. at Folsom	-	C	1	5	-	-	-	-	2
	South R. nr Mays Landing	-	-	-	-	-	(H)	-	-	-
4113.	Tuckahoe R. at Head of River	-	-	-	-	-	H	-	-	2
	Scotland Run at Malaga	-	-	-	-	-	(H)	-	-	-
4115.	Maurice R. at Norma	-	C	7	-	-	-	-	-	2
	Manumuskin R. nr Manumuskin	-	-	-	-	-	(H)	-	-	-
	Stow Cr. at Jericho	-	-	-	-	-	(H)	-	-	-
4385.	Delaware R. at Montague	-	C	6	3	-	-	4	2	2
4400.	Flat Br. nr Flatbrookville	B	-	-	-	-	H	-	-	2
4402.	Delaware R. below Tocks Island damsite, nr Delaware Water Gap, Pa.	-	C	5	3	-	-	4	2	6
4435.	Paulins Kill at Blairstown	-	C	7	-	-	-	1	-	2
4439.	Yards Cr. nr Blairstown	-	C	6	-	-	-	4	2	2
4455.	Pequest R. at Pequest	-	C	7	-	-	-	-	-	2
4465.	Delaware R. at Belvidere	-	C	3	2	7	-	4	2	2
4553.55	Beaver Br. at Weldon	-	-	-	-	-	H	-	-	2
4555.	Musconetcong R. at outlet of Lake Hopatcong	-	C	6	-	-	-	3	2	2
4560.	Musconetcong R. nr Hackettstown	-	C	2	3	7	-	3	2	2
4570.	Musconetcong R. nr Bloomsbury	-	C	7	2	-	-	3	2	2
4575.	Delaware R. at Riegelsville	-	-	-	-	-	U	-	-	-
4605.	Delaware & Raritan Can at Kingston	-	C	6	-	-	-	4	2	2
4635.	Delaware R. at Trenton	-	C	1	5	3	-	4	2	7
4640.	Assunpink Cr. at Trenton	-	C	3	7	-	-	4	-	2

Table A-1.—Purpose of gaging stations in operation and proposed for the network—concluded.

Station number	Station name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
4645.	Crosswicks Cr. at Extonville	-	C	5	7	-	-	-	-	2
4658.5	South Branch Rancocas Cr. at Vincentown	-	-	-	-	-	H	-	1	2
4665.	McDonalds Branch in Lebanon State Forest	B	-	-	-	-	H	-	-	1
4670.	North Branch Rancocas Cr. at Pemberton	-	C	3	-	-	-	-	-	2
4670.81	South Branch Pennsauken Cr. at Cherry Hill	-	-	-	-	-	H	-	-	2
4671.5	Cooper R. at Haddonfield	-	C	3	5	-	-	-	-	6
	South Branch Big Timber Cr. at Blackwood	-	-	-	-	-	(H)	-	-	-
4750.	Mantua Cr. at Pitman	-	C	7	-	-	-	-	1	2
4771.2	Raccoon Cr. nr Swedesboro	-	-	-	-	-	H	-	-	6
4825.	Salem R. at Woodstown	B	-	-	-	-	H	-	1	2
4830.	Alloway Cr. at Alloway	-	-	-	-	-	U	-	-	-

Note.—Abbreviations and column headings explained at beginning of Table A-1.

Table A-2.--Basin characteristics at gaging stations
(See pages 28-29 for definitions and explanations of basin characteristics)

Station number	Station name	Basin characteristics									
		A	S	L	St	E	F	P	I	T	Si
1-3680	Wallkill R. nr Unionville, N.Y.	140	16.5	25.1	5.3	0.7230	48	44	3.5	19	6.1
1-3770	Hackensack R. at Rivervale	58	4.38	21.6	5.1	.2150	65	43	3.5	24	3.3
1-3775	Pascack Br. at Westwood	29.6	36.2	15.4	3.7	.3380	40	43	3.5	24	3.2
1-3785	Hackensack R. at New Milford	113	4.1	25.0	5.1	.2300	51	43	3.5	24	3.2
1-3790	Passaic R. nr Millington	55.4	30.3	11.0	19.1	.3430	47	47	3.5	24	2.8
1-3795	Passaic R. nr Chatham	100	11.4	24.6	12.2	.3230	49	48	3.5	22	3.3
1-3805	Rockaway R. above reservoir at Boonton	116	11.9	28.5	7.7	.8060	83	48	3.5	20	4.3
1-3815	Whippany R. at Morristown	29.4	49.0	11.8	2.0	.5590	65	48	3.5	20	3.9
1-3845	Ringwood Cr. nr Wanaque	16.9	59.9	10.4	8.1	.7800	91	44	3.5	21	4.7
1-3850	Cupsaw Br. nr Wanaque	4.38	96.6	3.52	7.8	.6190	89	45	3.5	21	5.4
1-3860	West Br. nr Wanaque	11.8	179	4.89	4.4	.8290	100	45	3.5	20	5.2
1-3865	Blue Mine Br. nr Wanaque	1.71	275	2.35	1.1	.7900	100	45	3.5	20	5.4
1-3875	Ramapo R. nr Mahwah	118	17.4	24.2	5.6	.7790	77	44	3.5	22	4.1
1-3880	Ramapo R. at Pompton Lakes	160	12.9	35.7	5.8	.7000	79	44	3.5	22	4.3
1-3895	Passaic R. at Little Falls	762	1.83	53.2	9.6	.6090	72	46	3.5	22	3.7
1-3905	Saddle R. at Ridgewood	21.6	36.9	10.4	5.6	.3430	54	44	3.5	24	4.3
1-3910	Hohokus Br. at Hohokus	16.4	29.6	8.28	6.5	.3420	64	45	3.5	23	4.3
1-3915	Saddle R. at Lodi	54.6	16.6	18.8	5.0	.2600	47	45	3.5	24	3.3
1-3965	South Branch Raritan R. nr High Bridge	65.3	27.9	23.7	2.7	.8520	59	47	3.5	20	5.4
1-3970	South Branch Raritan R. at Stanton	147	26.9	35.0	1.8	.6650	52	46	3.5	22	4.5
1-3975	Walnut Br. nr Flemington	2.24	159	2.84	1.1	.4930	28	45	3.5	23	1.6
1-3980	Neshanic R. at Reaville	25.7	26.7	8.94	1.1	.2740	23	45	3.5	23	2.7
1-3985	North Branch Raritan R. nr Far Hills	26.2	44.4	8.22	1.8	.6490	59	49	3.5	24	5.4
1-3995	Lamington R. nr Pottersville	32.8	23.1	16.8	5.8	.7840	53	48	3.5	21	5.4
1-4000	North Branch Raritan R. nr Raritan	190	18.7	21.6	2.0	.4520	48	47	3.5	23	4.7
1-4005	Raritan R. at Manville	490	12.1	58.5	1.7	.4280	42	46	3.5	23	4.3
1-4010	Stony Br. at Princeton	44.5	10.4	18.5	1.2	.2590	42	43	3.5	24	3.7
1-4020	Millstone R. at Blackwells Mills	258	3.8	33.3	2.9	.1610	36	43	3.5	24	3.9
1-4030	Raritan R. at Bound Br.	779	11.6	60.8	2.1	.3270	39	45	3.5	23	4.1
1-4035	Green Br. at Plainfield	9.75	49.2	7.69	2.0	.2440	52	49	3.5	22	3.5
1-4050	Lawrence Br. at Farrington Dam	34.4	5.58	7.65	6.0	.1120	49	43	3.5	24	4.1
1-4055	South R. at Old Bridge	94.6	7.9	20.6	5.1	.1070	46	45	3.5	24	4.7
1-4075	Swimming R. nr Red Bank	48.5	12.7	10.6	2.4	.1300	33	45	3.5	26	3.5
1-4080	Manasquan R. at Squankum	43.4	6.46	12.8	2.2	.1180	37	45	3.5	26	5.2
1-4085	Toms R. nr Toms R.	124	7.24	19.3	14.6	.1090	85	46	3.5	23	9.6
1-4090	Cedar Cr. at Lanoka Harbor	56.0	7.7	14.2	13.3	.0959	97	47	3.5	23	10.0
1-4094	Mullica R. nr Batsto	46.1	6.69	18.3	29.4	.0842	85	46	3.5	24	9.2
1-4095	Batsto R. at Batsto	70.5	4.85	17.6	19.3	.0696	82	45	3.5	23	10.0
1-4100	Oswego R. at Harrisville	64.0	6.56	20.3	15.8	.1120	95	44	3.5	23	10.0

Table A-2.—Basin characteristics at gaging stations—concluded.
(See pages 28-29 for definitions and explanations of basin characteristics)

Station number	Station name	Basin characteristics									
		A	S	L	St	E	F	P	I	T	Si
1-4110	Great Egg Harbor R. at Folsom	56.3	3.14	18.6	14.9	0.1270	71	46	3.5	25	6.7
1-4115	Maurice R. at Norma	113	5.16	17.8	9.9	.1150	59	46	3.5	26	3.7
1-4120	Manantico Cr. nr Millville	22.3	7.04	8.14	8.2	.0888	40	45	3.5	26	3.2
1-4340	Delaware R. at Port Jervis, N.Y.	3,076	6.5	146.5	2.1	.9050	73	44	2.7	16	4.3
1-4385	Delaware R. at Montague	3,480	6.5	154.9	3.2	.9350	74	45	2.8	16	3.9
1-4400	Flat Br. nr Flatbrookville	65.1	36.2	25.1	2.5	.8950	87	44	3.5	18	4.7
1-4435	Paulins Kill at Blairstown	126	5.79	30.0	6.9	.6290	51	45	3.5	19	3.3
1-4450	Pequest R. at Huntsville	31.4	10.2	5.28	5.1	.6970	67	43	3.5	19	5.2
1-4455	Pequest R. at Pequest	108	8.02	21.8	6.0	.6680	65	42	3.5	20	5.2
1-4460	Beaver Br. nr Belvidere	36.2	24.2	14.2	4.0	.5680	50	45	3.5	21	2.7
1-4465	Delaware R. at Belvidere	4,535	5.6	203.5	3.5	.9380	74	45	3.0	16	3.7
1-4570	Musconetcong R. nr Bloomsbury	143	18.2	44.6	6.1	.7880	59	43	3.5	21	3.0
1-4575	Delaware R. at Riegelsville	6,328	5.3	226.4	3.3	.9550	71	44	3.1	16	3.2
1-4635	Delaware R. at Trenton	6,780	4.9	266.8	3.1	.9350	70	44	3.1	16	3.2
1-4640	Assunpink Cr. at Trenton	89.4	4.41	21.9	3.6	.1050	35	44	3.5	24	4.3
1-4645	Crosswicks Cr. at Extonville	83.6	5.47	15.8	8.8	.1180	62	44	3.5	24	5.6
1-4660	Middle Branch Mount Misery Br. in Lebanon State Forest	2.73	11.4	3.98	10.2	.1370	100	45	3.5	22	15.0
1-4665	McDonalds Branch in Lebanon State Forest	2.31	17.6	3.41	7.1	.1460	100	45	3.5	22	15.0
1-4670	North Branch Rancocas Cr. at Pemberton	111	6.41	17.7	15.0	.1170	88	44	3.5	24	8.5
1-4750	Mantua Cr. at Pitman	6.75	24.0	3.83	3.2	.1310	40	45	3.5	26	4.1
1-4766	Still Run nr Mickleton	3.95	23.0	3.83	1.8	.0717	19	43	3.5	26	3.3
1-4825	Salem R. at Woodstown	14.6	12.8	7.52	2.3	.1140	22	44	3.5	27	3.0
1-4830	Alloway Cr. at Alloway	21.9	14.4	8.52	4.1	.0810	42	44	3.5	27	2.3
1-4832	Blackbird Cr. at Blackbird, Del.	3.85	15.8	3.6	1.7	.064	44	44	3.2	26	3.7
1-4835	Leipsic R. nr Cheswold, Del.	9.35	10.2	5.1	1.0	.061	22	45	3.5	26	3.7
1-4850	Pocomoke R. nr Willards, Md.	60.5	1.49	14.9	16.8	.044	31	47	3.4	28	3.7
1-4855	Massawango Cr. nr Snow Hill, Md.	44.9	3.59	13.1	7.2	.046	86	47	3.4	28	3.7
1-4865	Beaverdam Cr. nr Salisbury, Md.	19.5	5.86	9.5	3.3	.050	49	46	3.4	28	3.7
1-4870	Nanticoke R. nr Bridgeville, Del.	75.4	32.3	14.3	2.7	.050	41	46	3.5	26	3.7
1-4875	Trap Pond Branch nr Laurel, Del.	16.7	4.82	7.5	2.6	.050	72	46	3.4	28	3.7
1-4885	Marshyhope Cr. nr Adamsville, Del.	44.8	2.65	11.9	1.3	.056	30	46	3.5	26	3.7
1-4890	Faulkner Branch at Federalsburg, Md.	7.10	7.65	5.5	1.5	.046	34	45	3.4	27	3.7
1-4900	Chicamacomico R. nr Salem, Md.	15.0	4.53	7.3	1.1	.028	51	45	3.5	28	3.7
1-4910	Choptank R. nr Greensboro, Md.	113	3.01	19.0	2.9	.060	36	45	3.5	26	3.7
1-4920	Beaverdam Branch at Matthews, Md.	5.85	14.8	4.1	1.0	.055	27	44	3.3	27	3.7
1-4930	Unicorn Branch nr Millington, Md.	22.3	6.06	9.9	2.5	.061	44	44	3.2	26	3.7
1-4935	Morgan Cr. nr Kennedyville, Md.	10.5	9.15	6.1	1.2	.060	9	43	3.2	26	3.7
1-4940	Southeast Cr. at Church Hill, Md.	12.5	10.6	5.6	1.0	.067	25	44	3.2	26	3.2

Table A-3.--Summary of regression equations for non-Coastal area.

$$Y = aA^{b_1} S^{b_2} L^{b_3} St^{b_4} E^{b_5} F^{b_6} P^{b_7} I^{b_8} T^{b_9}$$

Flow characteristic	Regression constant	Regression coefficients for basin characteristics									Standard error of estimate (percent)	Accuracy goals (standard error in percent) 10-year
		b ₁	b ₂	b ₃	b ₄	b ₅	b ₆	b ₇	b ₈	b ₉		
Y	a											
Q _a	0.818	1.05	0.10	-	0.091	-	-	-	-	-	9.4	9.4
SD _a	.380	1.01	-	-	.11	-	-	-	-	-	12	22
q ₁	.969	1.04	.11	-	.076	-	-	-	-	-	11	18
q ₂	.260	1.01	-	-	-	-	-	-	-	0.67	9.0	14
q ₃	1.56	1.05	.12	-	.072	-	-	-	-	-	11	12
q ₄	3.54	1.00	-	-	-	-	0.30	-	-1.21	-	11	14
q ₅	.106	1.02	-	-	-	0.17	.34	0.51	-	-	13	17
q ₆	.0796	1.02	-	-	.15	.47	-	.91	-	-	23	22
q ₇	.0703	1.07	-	-	-	.27	-	-	1.88	-	21	33
q ₈	.0255	1.08	-	-	-	-	-	-	2.59	-	17	38
q ₉	.527	1.04	-	-	.17	-	-	-	-	-	22	33
q ₁₀	.100	1.04	-	-	-	-	.48	-	-	-	27	35
q ₁₁	.359	1.11	.24	-	.14	-	-	-	-	-	12	23
q ₁₂	.612	1.07	.19	-	.074	-	-	-	-	-	12	19

Note.--For definitions and explanations of abbreviations see pages 26-30.

Table A-3.--Summary of regression equations for non-Coastal area.--continued

$$Y = aA^{b_1} S^{b_2} L^{b_3} St^{b_4} E^{b_5} F^{b_6} P^{b_7} I^{b_8} T^{b_9}$$

Flow characteristic	Regression constant	Regression coefficients for basin characteristics									Standard error of estimate (percent)	Accuracy goals (standard error in percent) 10-year
		b ₁	b ₂	b ₃	b ₄	b ₅	b ₆	b ₇	b ₈	b ₉		
Y	a											
SD ₁	1.11	0.98	-	-	-	-	-	-	-	-	19	22
SD ₂	1.71	1.06	0.12	-	-	-	-0.32	-	-	-	12	22
SD ₃	.449	1.09	.19	-	-	-	-	-	-	-	18	22
SD ₄	7.22	.97	-	-	-	-	-	-	-1.35	-	14	22
SD ₅	1.86	1.02	.14	-	0.10	-	-	-	-1.12	-	13	22
SD ₆	.0432	.98	-	-	-	0.43	-	1.11	-	-	34	22
SD ₇	1.10	.97	-	-	-	.29	-	-	-	-	28	22
SD ₈	.0693	1.00	-	-	-	-	-	-	2.18	-	17	22
SD ₉	.0378	1.19	-	-0.26	-	-	-	-	2.40	-	18	22
SD ₁₀	.138	.98	-	-	-	-	.47	-	-	-	25	22
SD ₁₁	.351	1.08	.19	-	.088	-	-	-	-	-	16	22
SD ₁₂	1.22	.98	-	-	-	.24	-	-	-	-	17	22

Note.--For definitions and explanations of abbreviations see pages 26-30.

Table A-3.--Summary of regression equations for non-Coastal area.--concluded

$$Y = aA^{b_1} S^{b_2} L^{b_3} St^{b_4} E^{b_5} F^{b_6} P^{b_7} I^{b_8} T^{b_9}$$

Flow charac- teristic	Regression constant	Regression coefficients for basin characteristics									Standard error of estimate (percent)	Accuracy goals (standard error in percent) 10-year	
		a	b ₁	b ₂	b ₃	b ₄	b ₅	b ₆	b ₇	b ₈			b ₉
Y	a												
Q ₂	3.56	0.96	0.28	-	-0.49	-	-	-	-4.11	2.27	35	15	
Q ₅	41.4	.95	.26	-	-.54	-	-	-	-	-	41	18	
Q ₁₀	46.8	.95	.29	-	-.53	-	-	-	-	-	42	20	
Q ₂₅	54.4	.95	.31	-	-.52	-	-	-	-	-	45	24	
Q ₅₀	49.2	.98	.35	-	-.51	-	-	-	-	-	47	26	
Q ₁₀₀	318	.87	-	-	-.73	-	-	-	-	-	55	28	
V _{7,2}	4.18	1.05	.12	-	-	-	-	-	-	-	18	12	
V _{7,10}	12.6	.99	-	-	-	-	-	-	-	-	21	16	
V _{7,50}	17.4	.98	-	-	-	-	-	-	-	-	24	21	
M _{7,2}	No meaningful equation derived											19	
M _{7,10}	No meaningful equation derived											26	
M _{7,20}	No meaningful equation derived											29	

Note.--For definitions and explanations of abbreviations see pages 26-30.

Table A-4.--Summary of regression equations for Coastal Plain area

$$Y = aA^{b_1} S^{b_2} St^{b_4} E^{b_5} F^{b_6} P^{b_7} T^{b_9} Si^{b_{10}}$$

Flow characteristic	Regression constant	Regression coefficients for basin characteristics								Standard error of estimate (percent)	Accuracy goals (standard error in percent) 10-year	
		a	b ₁	b ₂	b ₄	b ₅	b ₆	b ₇	b ₉			b ₁₀
Y	a											
Q _a	0.904	1.10	-	-	-	-	-	-	-	22	8.4	
SD _a	.420	1.01	-0.08	-	-	-	-	-	-	20	22	
q ₁	1.07	1.12	-	-	-	-	-	-	-	18	11	
q ₂	1.31	1.10	-	-	-	-	-	-	-	18	9.6	
q ₃	.124	1.08	-	-	-	-	0.96	-	-	16	10	
q ₄	.862	1.07	-	-	-	0.12	-	-	-	16	11	
q ₅	2.17	1.11	-	-	0.35	-	-	-	-	25	14	
q ₆	1.54	1.12	-	-	.37	-	-	-	-	34	14	
q ₇	1,490	1.13	.18	-	-	-	-	-2.57	-	41	19	
q ₈	.514	1.13	.14	-	-	-	-	-	-	29	22	
q ₉	3.28	1.06	-	-	.64	-	-	-	-	43	22	
q ₁₀	2.53	1.08	-	-	.60	-	-	-	-	44	17	
q ₁₁	1.92	1.09	-	-	.35	-	-	-	-	29	14	
q ₁₂	.856	1.12	-	-	-	-	-	-	-	22	11	

Note.--For definitions and explanations of abbreviations see pages 26-30.

Table A-4.--Summary of regression equations for Coastal Plain area--continued.

$$Y = aA^{b_1} S^2 S^{b_2} St^{b_4} E^{b_5} F^{b_6} P^{b_7} T^{b_9} Si^{b_{10}}$$

Flow characteristic	Regression constant	Regression coefficients for basin characteristics								Standard error of estimate (percent)	Accuracy goals (standard error in percent) 10-year
		b_1	b_2	b_4	b_5	b_6	b_7	b_9	b_{10}		
Y	a										
SD ₁	0.224	1.13	-	-	-0.44	-	-	-	-0.29	17	22
SD ₂	.110	1.10	-	-	-.56	0.21	-	-	-.45	19	22
SD ₃	.329	1.03	-0.15	-	-.40	-	-	-	-	21	22
SD ₄	.436	1.02	-.084	-	-.21	-	-	-	-	17	22
SD ₅	.0130	1.04	-	-	-	-	1.38	-	-	19	22
SD ₆	.317	1.11	-	-	-	-	-	-	-	26	22
SD ₇	.432	1.06	-	-	-	-	-	-	-	40	22
SD ₈	.181	1.07	-	-	-.53	-	-	-	-	33	22
SD ₉	.589	1.01	-	-	-	-	-	-	-	43	22
SD ₁₀	.298	.98	-	0.26	-	-	-	-	-	32	22
SD ₁₁	.502	1.10	-	.13	-	-	-	-	-	31	22
SD ₁₂	.207	1.19	-	-.17	-.25	-	-	-	-	24	22

Note.--For definitions and explanations of abbreviations see pages 26-30.

Table A-4.--Summary of regression equations for Coastal Plain area--concluded.

$$Y = aA^{b_1} S^{b_2} St^{b_4} E^{b_5} F^{b_6} P^{b_7} T^{b_9} Si^{b_{10}}$$

Flow characteristic	Regression constant	Regression coefficients for basin characteristics								Standard error of estimate (percent)	Accuracy goals (standard error in percent) 10-year
Y	a	b ₁	b ₂	b ₄	b ₅	b ₆	b ₇	b ₉	b ₁₀		
Q ₂	378	0.91	-	-	-	-0.59	-	-	-0.52	43	16
Q ₅	374	.98	-	-0.36	-	-.60	-	-	-	46	19
Q ₁₀	190	.90	-	-.43	-	-	-	-	-.61	49	22
Q ₂₅	299	.86	-	-.49	-	-	-	-	-.58	51	27
Q ₅₀	168	.98	-	-.83	-	-	-	-	-	51	30
Q ₁₀₀	No meaningful equation derived.										33
V _{7,2}	2.65	1.13	-	-	-0.33	-.19	-	-	-	22	12
V _{7,10}	2.60	1.15	-	-.18	-.36	-	-	-	-	23	16
V _{7,50}	19.5	1.07	-0.21	-	-.40	-.36	-	-	-	14	21
M _{7,2}	No meaningful equation derived.										13
M _{7,10}	No meaningful equation derived.										17
M _{7,20}	No meaningful equation derived.										20

Note.--For definitions and explanations of abbreviations see pages 26-30.

Table A-5.—Unregulated and regulated periods of record
for active and discontinued stations.

Station number	Station name	Drainage area (sq mi)	Natural flow period of record	Affected by regulation and/or diversion period of record
1-3680	Wallkill R. nr Unionville	144	1937-	
1-3770	Hackensack R. at Rivervale	58.0	1941-56	1956-
1-3775	Pascack Br. at Westwood	29.6		1934-
1-3785	Hackensack R. at New Milford	113		1921-
1-3786.9	Passaic R. at Bernardsville	8.83	1967-	
1-3790	Passaic R. at Millington	55.4	1903-6	1921-ab
1-3795	Passaic R. at Chatham	100	1903-11	1937-ab
1-3796.3	Russia Br. trib. at Milton	2.54	1968-	
1-3800	Beaver Br. at outlet of Splitrock Reservoir	5.50		1925-46
1-3805	Rockaway R. above reservoir, at Boonton	116		1937-b
1-3810	Rockaway R. below reservoir, at Boonton	119		1906-
1-3815	Whippany R. at Morristown	29.4	1921-	
1-3825	Pequannock R. at Macopin intake dam	63.7		1898-
1-3835	Wanaque R. at Awosting	27.1		1919-
1-3840	Wanaque R. at Monks	40.4		1934-
1-3845	Ringwood Cr. nr Wanaque	19.1	1934-	
1-3850	Cupsaw Br. nr Wanaque	4.38	1934-58	
1-3855	Erskine Br. nr Wanaque	1.14	1934-38	
1-3860	West Br. nr Wanaque	11.8	1934-	
1-3865	Blue Mine Br. nr Wanaque	1.71	1934-58	
1-3870	Wanaque R. nr Wanaque	90.4		1912-15, 1919-
1-3875	Ramapo R. nr Mahwah	118	1902-6; 1922-	
1-3880	Ramapo R. at Pompton Lakes	160	1939-53	(1921-39; 1953-)c
1-3885	Pompton R. at Pompton Plains	355	1903-4	1940-
1-3895	Passaic R. at Little Falls	762		1897-
1-3905	Saddle R. at Ridgewood	21.6	1954-	
1-3910	Hohokus Br. at Hohokus	16.4	1954-	
1-3915	Saddle R. at Lodi	54.6	1923-65	1965-a
1-3920	Weasel Br. at Clifton	4.45		1937-62e
1-3925	Second R. at Belleville	11.6		1937-64e
1-3930	Elizabeth R. at Irvington	2.91		1930-38e
1-3935	Elizabeth R. at Elizabeth	20.2		1921-e
1-3940	West Branch Rahway River at Millburn	7.1		1939-50
1-3945	Rahway R. nr Springfield	25.5		1938-e
1-3950	Rahway R. at Rahway	40.9		1921-e
1-3960	Robinsons Branch Rahway R. at Rahway	21.6		1939-
1-3965	South Branch Raritan R. nr High Bridge	65.3	1918-	
1-3968	Spruce Run at Clinton	41.3		1959-
1-3970	South Branch Raritan R. at Stanton	147	1903-6; 1919-63	1963-
1-3975	Walnut Br. nr Flemington	2.24	1936-61	
1-3980	Neshanic R. at Reaville	25.7	1930-	
1-3985	North Branch Raritan R. nr Far Hills	26.2	1921-	
1-3995	Lamington R. nr Pottersville	32.8	1921-	
1-4000	North Branch Raritan R. nr Raritan	190	1923-	
1-4005	Raritan R. at Manville	490		(1903-7; 1921-)b

Table A-5.—Unregulated and regulated periods of record
for active and discontinued stations.—continued

Station number	Station name	Drainage area (sq mi)	Natural flow period of record	Affected by regulation and/or diversion period of record
1-4007.3	Millstone R. at Plainsboro	65.8	1964-	
1-4009.32	Baldwin Cr. at Baldwin Lake nr Pennington	2.52	1962-	
1-4009.53	Honey Branch nr Pennington		1967-	
1-4010	Stony Brook at Princeton	44.70	1953-	
1-4015	Millstone R. at Kingston	171		1933-49b
1-4020	Millstone R. at Blackwells Mills	258		1921-b
1-4025.9	Royce Br. tributary at Frankford	.29	1966-	
1-4026	Royce Br. tributary nr Belle Mead	1.20	1969-	
1-4030.6	Raritan R. below Calco Dam, at Bound Brook	779	1903-9	1944-b
1-4035	Green Br. at Plainfield	9.75		1938-e
1-4040	Green Br. at Bound Brook	849	1923-31	
1-4045	Lawrence Br. at Patrick Corners	829	1922-26	
1-4050	Lawrence Br. at Farrington Dam	34.4		1927-h
1-4053	Matchaponix Br. at Spotswood	43.9		1957-67b
1-4054	Manalapan Br. at Spotswood	40.7		1957-
1-4055	South R. at Old Bridge	94.6		1939-h
1-4060	Deep Run at Browntown	8.07	1932-40	
1-4065	Tennent Br. nr Browntown	5.25	1932-41	
1-4070	Matawan Cr. at Matawan	6.11		1932-55
1-4075	Swimming R. nr Red Bank	48.5		1922-
1-4077.05	Shark R. nr Neptune City	9.96	1967-	
1-4077.6	Jumping Br. nr Neptune City	6.43	1967-	
1-4080	Manasquan R. at Squankum	43.4	1931-	
1-4085	Toms R. at Toms River	124	1928-	
1-4090	Cedar Cr. at Lanoka Harbor	56.0		1932-58
1-4090.95	Oyster Cr. nr Brookville	7.43	1965-	
1-4094	Mullica R. nr Batsto	46.1	1957-	
1-4095	Batsto R. at Batsto	70.5		1927-hi
1-4100	Oswego R. at Harrisville	64.0	1930-	
1-4105	Absecon Cr. at Absecon	16.6		1923-29; 1933-38; 1946-
1-4110	Great Egg Harbor R. at Folsom	56.3	1925-	
1-4113	Tuckahoe R. at Head of River	30.8	1969-	
1-4115	Maurice R. at Norma	113	1932-	
1-4120	Manantico Cr. nr Millville	22.3		1931-57hi
1-4125	West Branch Cohansey R. at Seeley	2.55		1951-67
1-4130	Loper Run nr Bridgeton	2.34		1937-59
1-4340	Delaware R. at Port Jervis, N.Y.	3,076	1904-25	1925-k
1-4385	Delaware R. at Montague	3,480		1939-k
1-4400	Flat Br. nr Flatbrookville	65.1	1923-	
1-4402	Delaware R. below Tocks Island damsite nr Delaware Water Gap Pa.	3,850		1964-
1-4435	Paulins Kill at Blairstown	126	1921-	
1-4439	Yards Cr. nr Blairstown	7.16		1967-
1-4450	Pequest R. at Huntsville	31.4	1939-62	
1-4455	Pequest R. at Pequest	108	1921-	
1-4460	Beaver Br. nr Belvidere	36.2	1922-61	

Table A-5.--Unregulated and regulated periods of record
for active and discontinued stations.--concluded

Station number	Station name	Drainage area (sq mi)	Natural flow period of record	Affected by regulation and/or diversion period of record
1-4465	Delaware R. at Belvidere	4,535	1922-25	1925-k
1-4552	Pohatcong Cr. at New Village	33.4	1959-69	
1-4553.55	Beaver Br. at Weldon	1.74	1969	
1-4555	Musconetcong R. at outlet of Lake Hopatcong	25.6		1928-
1-4560	Musconetcong R. nr Hackettstown	70.0		1921-
1-4570	Musconetcong R. nr Bloomsbury	143	1903-7; 1921-	
1-4575	Delaware R. at Riegelsville	6,328		1906-k
1-4605	Delaware & Raritan Canal at Kingston	-		1947-
1-4635	Delaware R. at Trenton	6,780		1912-k
1-4640	Assumpink Cr. at Trenton	89.4	1923-54	1954-e
1-4645	Crosswicks Cr. at Extonville	83.6	1940-	
1-4658.5	South Branch Rancocas Cr. at Vincentown	53.3	1961-	
1-4660	Middle Branch Mount Misery Br. in Lebanon State Forest	2.73	1952-65	
1-4665	McDonalds Branch in Lebanon State Forest	2.31	1953-	
1-4670	North Branch Rancocas Cr. at Pemberton	111	1921-	
1-4670.81	South Branch Pennsauken Cr. at Cherry Hill	9.16	1967-	
1-4671.5	Cooper R. at Haddonfield	17.4	1963-	
1-4750	Mantua Cr. at Pitman	6.75	1940-	
1-4766	Still Run nr Mickleton	3.95	1957-66	
1-4771.2	Raccoon Cr. nr Swedesboro	29.9	1966-	
1-4775	Oldmans Cr. nr Woodstown	19.3	1931-40	
1-4825	Salem R. at Woodstown	14.6	1940-	
1-4830	Alloway Cr. at Alloway	21.9	1952-	

- a Diversion for municipal supply only; monthly and annual discharge may be adjusted to natural flow conditions.
- b Insignificant effect on medium and high flows.
- c Adjusted monthly discharge within reasonable limits. Effect on high flows less than 10 percent.
- d Water diverted above station since October 1965. Monthly discharge adjusted for diversion.
- e Also significant effect on runoff due to urbanization.
- f Includes 2.2 sq mi which contributes to a storm sewer which bypasses the station.
- g Approximately.
- h Effect on high flows is less than 10 percent.
- i Monthly and annual mean discharge affected insignificantly.
- k Monthly and annual mean flows have been adjusted for storage, diversion, and evaporation (from man-made lakes) for water years 1923-62.

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