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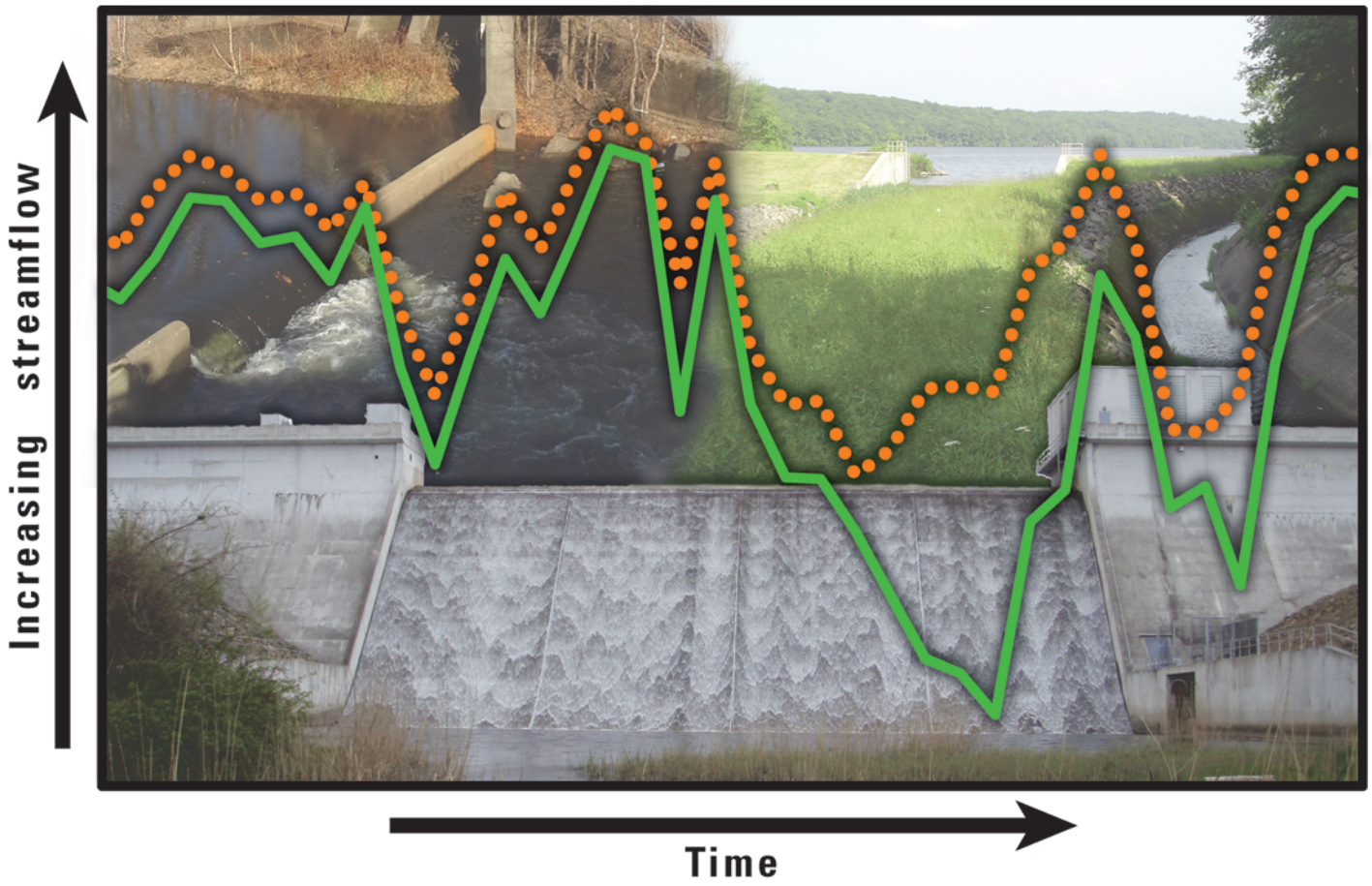
Methods Used to Reconstruct Historical Daily Streamflows in Northern New Jersey and Southeastern New York, Water Years 1922–2010



Scientific Investigations Report 2018–5068

U.S. Department of the Interior
U.S. Geological Survey

Cover. Reconstructed streamflow values (orange, dotted line) are calculated from observed streamflow (green line) and adjusted for effects of diversions and reservoir storage, providing what streamflow would have been without those components of water use. Photos of U.S. Geological Survey (USGS) streamgage: (clockwise from upper left) 01388500 Pompton River at Pompton Plains, NJ, by Bob Atkinson, USGS; 01382430 Mathews Brook diversion near Macopin, NJ, by Amy McHugh, USGS; and 01382381 Pequannock River at Charlotteburg, NJ, by Richard Edwards, USGS.

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U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2018

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27) and the North American Datum of 1983 (NAD 83).

Abbreviations

MOVE1	Maintenance of Variance Extension type 1
NJDEP	New Jersey Department of Environmental Protection
NJGWS	New Jersey Geological and Water Survey
USGS	U.S. Geological Survey

Methods Used to Reconstruct Historical Daily Streamflows in Northern New Jersey and Southeastern New York, Water Years 1922–2010

By R. Edward Hickman and Amy R. McHugh

Abstract

A study was conducted by the U.S. Geological Survey, in cooperation with the New Jersey Department of Environmental Protection, to reconstruct streamflows for use in the RiverWare model. Methods and data used to estimate daily reconstructed streamflows at 53 sites in selected subbasins in northern New Jersey and southeastern New York are presented in the report. These subbasins contain one or more surface-water diversions that are operated or have been operated in the past by water purveyors or the New Jersey Department of Environmental Protection. Reconstructed streamflows are estimates of those streamflows that would have occurred without the effects of changes in reservoir storage or surface-water diversions by water purveyors.

Reconstructed flows at 47 sites were determined from monthly observed streamflows, changes in reservoir storage, and surface-water diversions. Monthly reconstructed streamflows were calculated directly for those months with sufficient data. Missing monthly reconstructed flows were estimated from relations between selected calculated values of monthly reconstructed flows and monthly observed flows at selected index gages. Daily reconstructed flows were determined from the disaggregation of monthly reconstructed flows on the basis of daily observed flows at selected streamgages. At six sites, reconstructed flows were determined from relations between discrete measurements of observed streamflows and daily observed streamflows at selected index gages.

Introduction

Surface-water diversions from rivers and reservoirs in the basins of the Passaic and Hackensack Rivers in northern New Jersey and southeastern New York are important sources of water supply within and outside these basins (Storck and Nawyn, 2001). The diversions, operated by water purveyors, remove water to be treated and distributed for use or transfer water from one river basin to another. Some purveyors divert water from a stream or reservoir and transfer it to another purveyor.

The New Jersey Department of Environmental Protection (NJDEP) is responsible for regulating water purveyors in the State and for setting a safe yield for each water-supply reservoir system. “Safe yield” is defined as “that maintainable yield of water from a surface or groundwater source or sources which is available continuously during projected future conditions, including a repetition of the most severe drought of record, without creating undesirable effects, as determined by the Department” (New Jersey Department of Environmental Protection, 2011). “Department” is the New Jersey Department of Environmental Protection.

To aid in determining the safe yields of the surface-water-supply reservoir system, the NJDEP created a RiverWare computer model that simulates streamflow, reservoir storage, and surface-water diversions. The RiverWare model (Center for Advanced Decision Support for Water and Environmental Systems, n.d.) is a physically based, water-accounting model used to simulate water movement down a river while including effects of reservoir storage, diversions, and tributary streamflow. The RiverWare model was used by the NJDEP to simulate daily streamflow, reservoir storage, and surface-water diversions throughout selected subbasins of the Passaic and Hackensack Rivers and some adjacent streams during water years[1] 1922–2010.

Daily streamflow measurements during water years 1922–2010 at points (referred to as “flow-reconstruction sites”) in subbasins of the Passaic and Hackensack Rivers and some adjacent streams are a required input to the RiverWare model. These streamflows, referred to as “reconstructed streamflows,” are estimates of the streamflow that would have occurred if there were no reservoir storage and no surface-water withdrawals by any of the purveyors included in the study. The USGS, in cooperation with the NJDEP, conducted a study to provide these required data for the RiverWare model.

[1] A water year is the 12-month period beginning October 1 and ending September 30; it is designated by the calendar year in which it ends.

Purpose and Scope

The purpose of this report is to describe the data and methods used to estimate daily reconstructed streamflow at 53 sites (flow-reconstruction sites) in subbasins of the Passaic and Hackensack Rivers and some adjacent streams in northern New Jersey and southeastern New York during water years 1922–2010. The reconstructed streamflows are not intended to fully represent natural conditions because surficial aquifer withdrawals and effluent return flows were not included.

Selected features in each reconstruction subbasin and the application of the methods are described. In addition, the resulting reconstructed streamflows are discussed. A companion data release includes selected data used for calculations so that comparisons of reconstructed flows can be made between sites.

Description of Study Area

The study area consists of two groups of subbasins in northern New Jersey and southeastern New York State (fig. 1). One group, referred to as "reconstruction subbasins," includes those subbasins for which reconstructed flows are determined and encompasses an area of 986 square miles (mi^2). The second group of subbasins, referred to as "index subbasins," includes the subbasins that drain to selected streamgages (hereafter "index gages"). The records of streamflow from the index gages were used to estimate reconstructed flows in the reconstruction subbasins. The group of index subbasins encompasses an area of 232 mi^2.

Index Subbasins

Two index subbasins were used in the study (table 1, fig. 2). The Paulins Kill subbasin consists of the 126-mi^2 area draining to the index gage on the Paulins Kill at Blairstown, N.J. (station number 01443500). The Pequest River subbasin consists of the 106-mi^2 area draining to the index gage on the Pequest River at Pequest, N.J. (01445500).

These index gages were so designated because of their location within the glacial extent and long record of streamflow (table 1, fig. 2), and because the variation over time of the streamflow at each gage appears to be due primarily to weather and not to changes in basin characteristics. The period of record for the streamgage on the Pequest River (01445500) is complete for water years 1922–2010 and that for the streamgage on the Paulins Kill (01443500) is complete for water years 1922–2010, except for 1977. Esralew and Baker (2008) examined records of streamflow at these gages for changes over water years 1922–2005 owing to changes in basin characteristics. They could identify no changes in the streamflow in the Paulins Kill but did identify a change in peak streamflows in the Pequest River about 1960 as a result of channelization. Only an identified change in daily streamflow at the index gage would present a problem in determining reconstructed streamflows in the context of this report.

Reconstruction Subbasins

The reconstruction subbasin group consists of 13 subbasins (table 2, fig. 3); each stream in the subbasins is tributary to, or part of, one of following major rivers: Passaic River, Hackensack River, Hudson River, or Delaware River. Each of the reconstruction subbasins contains (or has contained) one or more surface-water diversions operated by either selected water purveyors or the NJDEP.

The 13 reconstruction subbasins range in size from 4.62 to 259 mi^2 (table 2, fig. 3). Each subbasin was designated largely on the basis of the hydrologic information (observed streamflow, rates of transfer at surface-water diversions, and reservoir storage) for the outflow point (table 2). The hydrologic information for the outlet of each reconstruction subbasin varied by subbasin (table 2). For most outlets, there was a record of daily streamflows. For two outlets (Double Kill and Longhouse Creek), the records contained only discrete streamflow measurements. For three outlets (Hirshfeld Brook, Wanaque River, and Rockaway River), the records contained surface-water diversions. For this report, all surface-water

Table 1. Description of index subbasins with index streamgages in northern New Jersey.

[Latitude and longitude in degrees, minutes, seconds; datum for latitude and longitude is North American Datum of 1983. USGS, U.S. Geological Survey; N.J., New Jersey]

Index subbasin	Index streamgage				
	USGS station name (station number)	Latitude	Longitude	Drainage area (square miles)	Period of published streamflow data from USGS records, during water years 1922-2014 (record is complete unless otherwise indicated)
Paulins Kill	Paulins Kill at Blairstown, N.J. (01443500)	405851	0745712	126	1922–2014 incomplete record for water year 1977
Pequest River	Pequest River at Pequest, N.J. (01445500)	404950	0745840	106	1922–2014

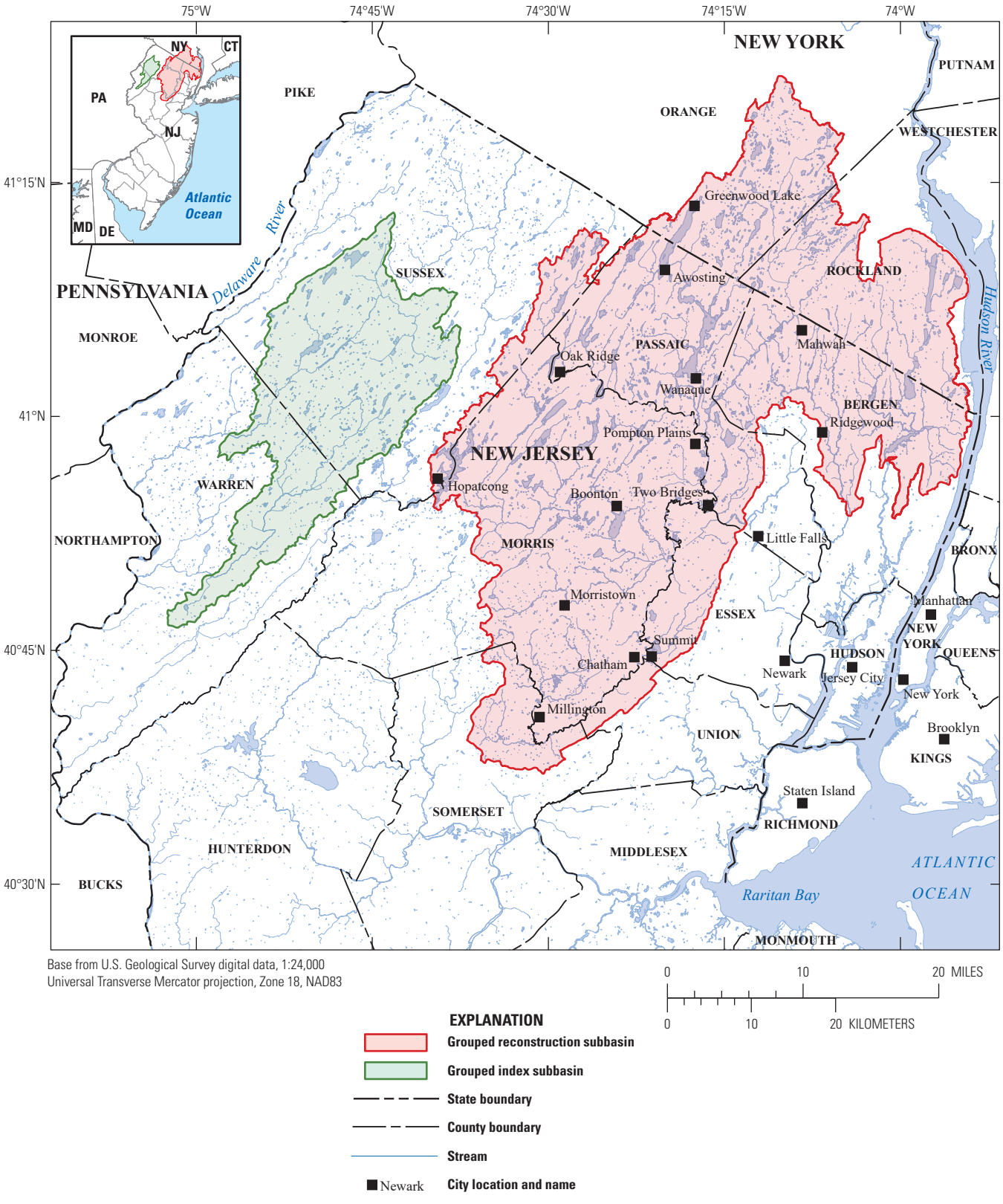

Figure 1. Groups of reconstruction subbasins and index subbasins in northern New Jersey and southeastern New York.

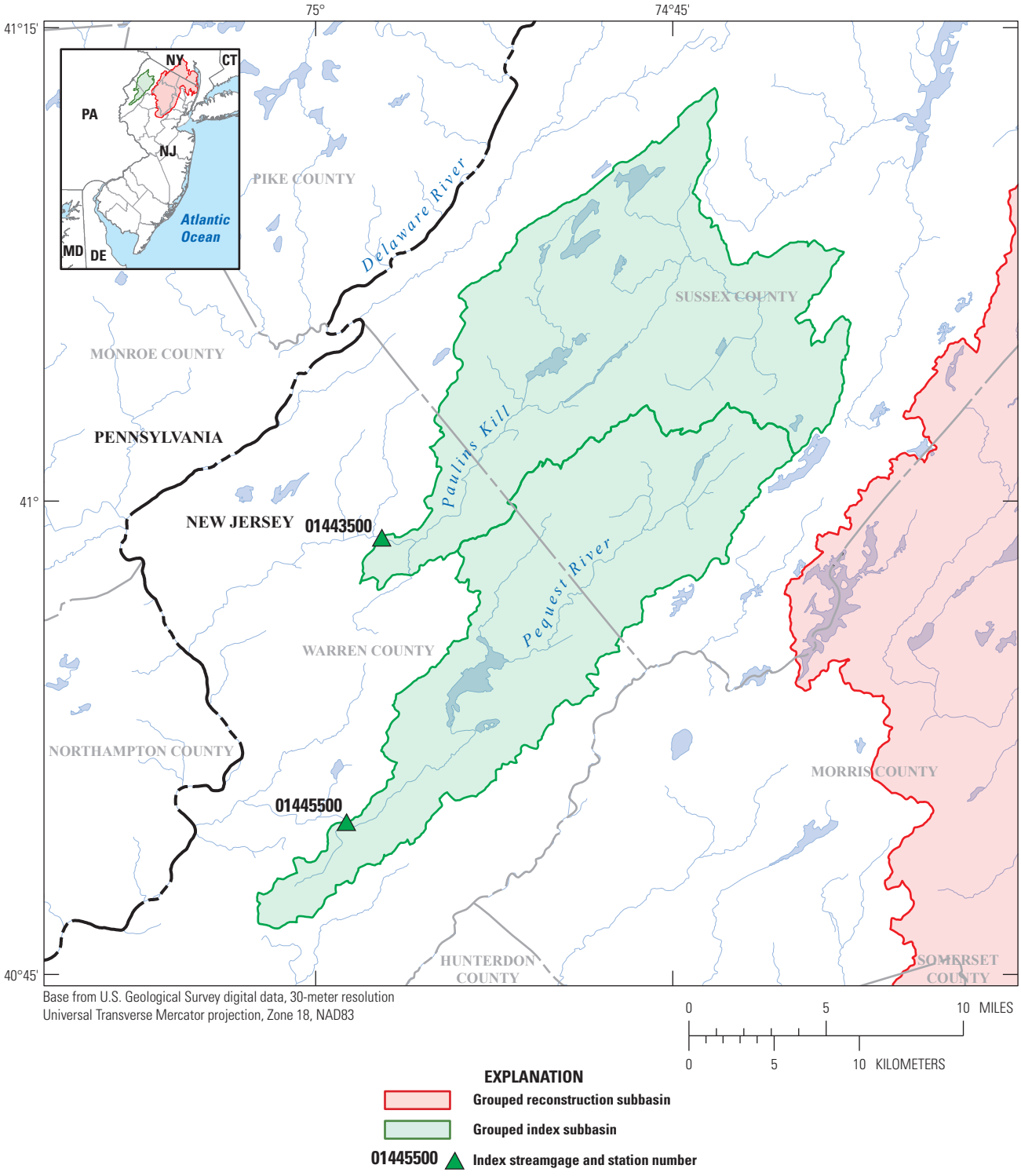

Figure 2. Index subbasins and index gages in northern New Jersey.

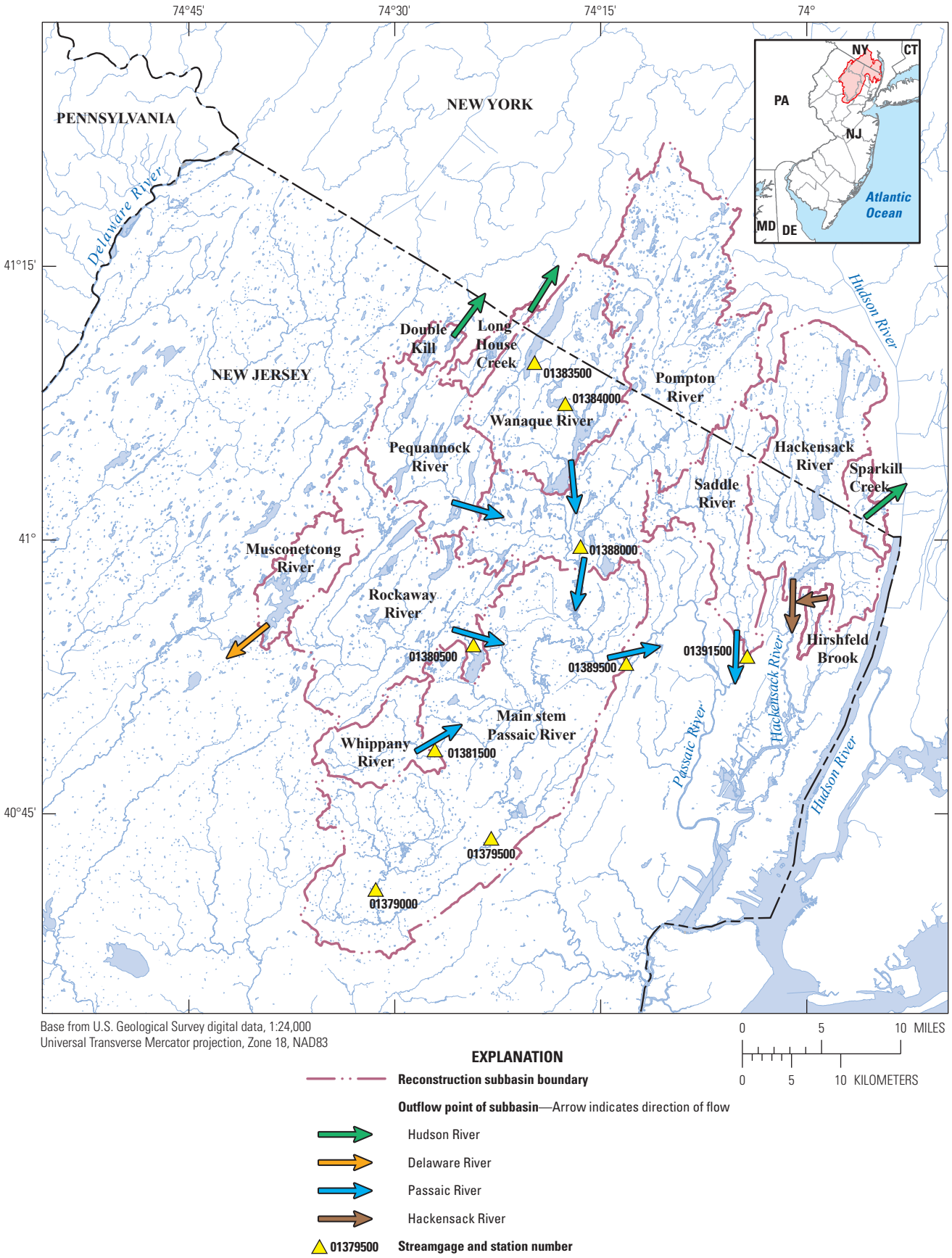

Figure 3. Reconstruction subbasins, outlets of each subbasin, and selected streamgages used to disaggregate monthly reconstructed streamflows in northern New Jersey and southeastern New York.

Table 2. Description of reconstruction subbasins in northern New Jersey and southeastern New York.

[Latitude and longitude in degrees, minutes, seconds; USGS, U.S. Geological Survey; NAD 83, North American Datum of 1983; NAD 27, North American Datum of 1927; n.a., not applicable; N.Y., New York; N.J., New Jersey]

Subbasin	Drainage area (square miles)	Tributary of major river basin	Outflow point of subbasin					Next upstream subbasins	Next downstream subbasin
			USGS station name (number)	Hydrologic information at outflow point[1]	Latitude	Longitude	Datum for latitude and longitude		
Sparkill Creek	10.7	Hudson River	Sparkill Creek at Sparkill, N.Y. (01376280)	Daily streamflow	410144	0735532	NAD83	n.a.	n.a.
Saddle River	54.6	Passaic River	Saddle River at Lodi, N.J. (01391500)	Daily streamflow	405325	0740450	NAD83	n.a.	n.a.
Hackensack River	113	Hackensack River	Hackensack River at New Milford, N.J. (01378500)	Daily streamflow	405654	0740136	NAD83	n.a.	n.a.
Hirshfeld Brook	4.62	Hackensack River	Hirshfeld Brook at diversion at New Milford, N.J. (n.a.)	Surface-water diversion	405651	0740121	NAD83	n.a.	n.a.
Double Kill	6.46	Hudson River	Double Kill at Wawayanda, N.J. (01368820)	Discrete streamflow measurements	411113	0742512	NAD83	n.a.	n.a.
Pequannock River	63.7	Passaic River	Pequannock River at Macopin Intake Dam, N.J. (01382500)	Daily streamflow	410106	0742404	NAD83	n.a.	Pompton River
Long House Creek	8.33	Hudson River	Long House Creek at Cascade Lake, N.Y. (01368722)	Discrete streamflow measurements	411253	0742002	NAD27	n.a.	n.a.
Wanaque River	90.4	Passaic River	Wanaque River at Wanaque, N.J. (01387000)	Daily streamflow; surface-water diversion	410239	0741735	NAD83	n.a.	Pompton River
Pompton River	201	Passaic River	Pompton River at Pompton Plains, N.J. (01388500)	Daily streamflow	405811	0741655	NAD 83	Wanaque River and Pequannock River	Main Stem Passaic River
Musconetcong River	25.3	Delaware River	Musconetcong River at outlet of Lake Hopatcong, N.J. (01455500)	Daily streamflow	405502	0743956	NAD 83	n.a.	n.a.
Rockaway River	119	Passaic River	Rockaway River below Reservoir at Boonton, N.J. (01381000)	Daily streamflow; surface-water diversion	405349	0742341	NAD 83	n.a.	Main Stem Passaic River
Whippany River	29.4	Passaic River	Whippany River at Morristown, N.J. (01381500)	Daily streamflow	404826	0742725	NAD 83	n.a.	Main Stem Passaic River
Main stem Passaic River	259	Passaic River	Passaic River at Little Falls, N.J. (01389500)	Daily streamflow	405305	0741334	NAD 83	Rockaway River, Whippany River, and Pompton River	n.a.

[1]For this report, all surface-water diversions from reservoirs are considered to be located at the reservoir outlet.

diversions from reservoirs were considered to occur at the reservoir outlet.

Detailed maps of the reconstruction subbasins are presented in figures 4 (Hackensack River, Saddle River, Hirshfeld Brook, and Sparkill Creek), 5 (Pequannock River and Double Kill), 6 (Wanaque River and Long House Creek), 7 (Pompton River), 8 (Rockaway River, Musconetcong River, and Whippany River), and 9 (Main Stem Passaic River). The maps show some or all of the following selected features: reservoirs, surface-water diversions transferring water out of the subbasin, continuous-record streamgages, partial-record stations, and the flow-reconstruction sites. Surface-water diversions transferring water into a subbasin are not shown.

Reservoirs

Reservoirs included in this analysis were selected because information on end-of-month storage was available (table 3, figs. 4–9); reservoirs are identified by short names. Information for some small reservoirs or those without known operations of storage change shown in maps and (or) mentioned in the text was not used in the analysis.

Surface-Water Diversions

A diversion is the taking of water from a stream or other body of water into a canal, pipe, or other conduit (Langbein and Iseri, 1960). For this report, diversions include those features that remove water from a surface-water body (either a stream or reservoir) for either (1) transfer into another stream channel or reservoir or (2) treatment and distribution for use. Only surface-water diversions by selected water purveyors and the NJDEP were included in this analysis; surface-water diversions by other entities and all groundwater diversions were not included.

Twenty-six surface-water diversions were included in this study (table 4, figs. 4–9). These are or have been operated by eight water purveyors and the NJDEP. In this report, diversions are identified with a diversion index number. Most, but not all, diversions have an associated USGS station number.

Two types of surface-water diversions are considered in this report—pipe and dam (table 4, figs. 4–9). Of the 26 surface-water diversions considered, 22 are pipe diversions, and 4 are dam diversions. A pipe diversion is defined as the taking of water from a reservoir or stream channel through a pipe by the action of pumping or gravity. Dam diversions are those that transfer water out of one stream channel and into an adjacent stream channel as the result of the installation of a weir (a low dam) in the first stream channel.

Streamgages

Records for 27 selected streamgages (table 5, figs. 4–9) were used to reconstruct streamflows. A streamgage is a facility that measures and records continuous streamflow. The streamflow measured at streamgages is labeled “observed.” Streamgages mentioned in the study are or were operated by the USGS and are identified by name and station number.

Partial-Record Stations

Discrete measurements of observed streamflow at six partial-record stations (table 6, figs. 4–9) were used to determine reconstructed streamflows at some sites. Partial-record stations are locations where discrete measurements of streamflow have been systematically collected over time to answer a particular question. All partial-record stations mentioned in this study were established and operated by the USGS; these stations are identified by the station name and number.

Flow-Reconstruction Sites

Flow-reconstruction sites are those locations for which reconstructed flows were determined (table 7, figs. 4–9). Most sites were selected by the New Jersey Geological and Water Survey (part of the New Jersey Department of Environmental Protection) to provide information for the RiverWare model. Nearly all sites are at streamgages, reservoir outlets, or points of diversion. A few sites at streamgages in the Rockaway River (Recon41), Whippany River (Recon44, Recon45), and Passaic River (Recon49) subbasins were added by the USGS, most of them to help determine reconstructed flows at sites selected by the NJDEP. Flow-reconstructions sites are identified by name and index number.

Description of Selected Features in Each Reconstruction Subbasin

The discussion of selected features is organized into groups of reconstruction subbasins adjacent to one another. Features presented include surface-water diversions, reservoirs, streamgages, partial-record stations, and flow-reconstruction sites.

Hackensack River, Saddle River, Hirshfeld Brook, and Sparkill Creek

The subbasins of the Hackensack River, Saddle River, Hirshfeld Brook, and Sparkill Creek are in the eastern part of the group of reconstruction subbasins (fig. 3). Features of the Hackensack River subbasin (fig. 4) include 4 reservoirs (table 3), 3 pipe diversions (table 4), 4 streamgages (table 5), and 7 flow-reconstruction sites (table 7). Three of the reservoirs—DeForest Lake, Lake Tappan, and Oradell Reservoir—are on the Hackensack River; the fourth reservoir, Woodcliff Lake, is on Pascack Brook, a tributary to the Hackensack River. One pipe diversion transfers water out of each of the following: DeForest Lake (Div02), the Hackensack River at West Nyack (Div03), and the Oradell Reservoir (Div04). Transferred water is treated and distributed for use. Three of the four streamgages are on the Hackensack River at West Nyack, N.Y. (01376800); Rivervale, N.J. (01377000); and New Milford, N.J. (01378500). The remaining streamgage is on Pascack Brook at Westwood, N.J. (01377500).

Seven flow-reconstruction sites were designated for the Hackensack River subbasin (fig. 4, table 7).

Flow-reconstruction sites share locations with the following streamgages: Hackensack River at West Nyack, N.Y. (Recon04); Hackensack River at Rivervale, N.J. (Recon06); Pascack Brook at Westwood, N.J. (Recon08); and Hackensack River at New Milford, N.J. (Recon09). The remaining sites are at the outlets of DeForest Lake (Recon03), Lake Tappan (Recon05), and Woodcliff Lake (Recon07).

Features of the Saddle River subbasin (fig. 4) consist of 1 pipe diversion (table 4), 4 streamgages (table 5), and 4 flow-reconstruction sites (table 7). The diversion Saddle River at Paramus, N.J. (Div06), transfers water into the Hackensack River subbasin. This water is pumped from the Saddle River between the diversion site and the streamgage at Saddle River below Hohokus Brook at Paramus, N.J. (01391102) and is transferred to the Musquapsink Brook, a tributary to Pascack Brook. The four streamgages are on the Saddle River at Upper Saddle River, N.J., (01390450); Ridgewood, N.J. (01390500); below Hohokus Brook at Paramus, N.J. (01391102); and Lodi, N.J. (01391500). The four flow-reconstruction sites are on the Saddle River below diversion at Paramus, N.J. (Recon13), and at the streamgages at Upper Saddle River, N.J. (Recon11); Ridgewood, N.J. (Recon12); and below Hohokus Brook at Paramus, N.J. (Recon14).

Features of the Hirshfeld Brook subbasin (fig. 5) consist of 1 pipe diversion (table 4), 1 partial-record station (table 6), and 1 flow-reconstruction site (table 7). The pipe diversion (Div05) is at the downstream end of the subbasin and transfers water to the Oradell Reservoir in the Hackensack River subbasin. The partial-record station is at New Milford, N.J. (01378520), upstream from the diversion. The flow-reconstruction site (Recon10) is at the point of the pipe diversion.

Features of the Sparkill Creek subbasin (fig. 4) consist of 1 pipe diversion (table 4), 1 streamgage (table 5), and 2 flow-reconstruction sites (table 7). The pipe diversion, Sparkill Creek diversion at Northvale, N.J. (Div01; table 4), transfers water into the Hackensack River subbasin; water was pumped from Sparkill Creek and discharged into a tributary to Dorotockeys Run, which flows into the Oradell Reservoir. The streamgage on Sparkill Creek at Sparkill, N.Y. (01376280), at the downstream end of the subbasin was discontinued in water year 1978. Flow-reconstruction sites were designated at the site of the diversion (Recon01) and the discontinued streamgage (Recon02).

Pequannock River and Double Kill

The subbasins of the Pequannock River and Double Kill are in the northwestern part of the group of reconstruction subbasins (fig. 3). Features of the Pequannock River subbasin (fig. 5) include 5 reservoirs (table 3), 3 diversions (table 4), 1 streamgage (table 5), and 11 flow-reconstruction sites (table 7). The reservoirs are Canistear, Oak Ridge, Clinton, Charlotteburg, and Echo Lake. Storage in the other ponds in the subbasin was not included in the analysis. Two of the diversions are dam diversions. The dam diversion on the Pequannock River near Stockholm, N.J. (Div08), transferred water to the Canistear Reservoir through 1977. The other dam diversion, Mathews Brook diversion near Macopin, N.J. (Div10), transfers water from Mathews Brook to Echo Lake. The pipe diversion on the Charlotteburg Reservoir at Charlotteburg, N.J. (Div09), transfers water directly for treatment, then distribution to the City of Newark. The one streamgage is on the Pequannock River at the outlet of the subbasin at Macopin Intake Dam, N.J. (01382500).

There are 11 flow-reconstruction sites in the Pequannock River subbasin (table 7, fig. 5). One (Recon16) is at the site of the dam diversion on the Pequannock River to the Canistear Reservoir. Five sites are at the outlets of the selected reservoirs: Canistear Reservoir (Recon17), Oak Ridge Reservoir (Recon19), Clinton Reservoir (Recon22), Charlotteburg Reservoir (Recon23), and Echo Lake (Recon25). One site is at the dam diversion of Mathews Brook into Echo Lake (Recon24). Three sites are at outlets of the following ponds: Dunker Pond (Recon18), Hanks Pond (Recon20), and Cedar Pond (Recon21). The last flow-reconstruction site (Recon26) is at the streamgage on the Pequannock River at Macopin Intake Dam, N.J. (01382500), at the subbasin outlet.

The Double Kill subbasin (fig. 5) contains the following selected features: 1 discontinued pipe diversion (table 4), 1 partial-record station (table 6), and 1 flow-reconstruction site (table 7). The pipe diversion (Div07) transferred water from Lake Wawayanda to the Pequannock River subbasin during water years 1966 and 1980–81; water was pumped into Cherry Ridge Brook, a tributary to Canistear Reservoir in the Pequannock River subbasin. The partial-record station, Double Kill at Wawayanda, N.J. (01368820), is at the downstream end of the Double Kill subbasin. The flow-reconstruction site (Recon15) is on the Double Kill at the outlet of Wawayanda Lake.

Wanaque River and Long House Creek

The Long House Creek and Wanaque River subbasins are in the northern part of the group of reconstruction subbasins (fig. 3). Selected features of the Wanaque River subbasin (fig. 6) include 3 reservoirs (table 3), 2 pipe diversions (table 4), 3 streamgages (table 5), and 3 flow-reconstruction sites (table 7). The three reservoirs are Greenwood Lake, Monksville Reservoir, and Wanaque Reservoir. Both pipe diversions remove water from Wanaque Reservoir. One diversion transfers water for treatment and distribution for use (Div12), and the other transfers water to Oradell Reservoir in the Hackensack River subbasin (Div13). The three selected streamgages measure or have measured streamflow in the Wanaque River (table 5). The streamgages that measure the streamflow leaving Greenwood Lake at Awosting, N.J. (01383500), and the streamflow downstream from the Wanaque Reservoir at Wanaque, N.J. (01387000), are currently (2018) in operation. The third streamgage at Monks, N.J. (01384000), operated until water year 1985 when it was removed prior to the construction of the Monksville Reservoir. The three flow-reconstruction sites are at the sites of the streamgages at Awosting, N.J. (Recon29); Monks, N.J. (Recon30); and Wanaque, N.J. (Recon31).

The Long House Creek subbasin (fig. 6) contains the following selected features: 1 dam diversion (table 4), 2 partial-record stations (table 6), and 2 flow-reconstruction sites (table 7). The dam diversion, Auxiliary outlet of Upper Greenwood Lake at Moe, N.J. (Div11), transfers water from the Long House Creek subbasin into the Wanaque River subbasin; water is released into Green Brook, then flows into Greenwood Lake. The partial-record station at this location (01368720) measures the amount of this transfer. The other partial-record station on the Long House Creek below Cascade Lake, N.Y. (01376822), measures the amount of streamflow in Long House Creek at the outlet of the Long House Creek subbasin downstream from Upper Greenwood Lake. The two flow-reconstruction sites (table 7) are at the diversion from Upper Greenwood Lake at Moe into Green Brook (Recon27) and on Long House Creek at the outlet from Upper Greenwood Lake (Recon28).

Pompton River

The Pompton River subbasin is in the central part of the group of reconstruction subbasins (fig. 3). The Pompton River subbasin contains reaches of the following streams: Ramapo River, Pequannock River, Wanaque River, Posts Brook, Stone House Brook, Haycock Brook, and Pompton River (fig. 7). The Ramapo, Pequannock, and Wanaque Rivers and Haycock Brook are all tributaries to the Pompton River. Stone House Brook is a tributary to the Pequannock River, and Posts Brook is a tributary to the Wanaque River.

Storage at the two reservoirs mentioned in the discussion of this subbasin—Point View Reservoir and Butler Reservoir—were not included in the analysis. Point View Reservoir is on Haycock Brook, and Butler Reservoir is on Stone House Brook.

Selected features of the Pompton River subbasin (fig. 7) include 5 diversions (table 4), 3 streamgages (table 5), 2 partial-record stations (table 6), and 6 flow-reconstruction sites (table 7). Four of the diversions are pipe diversions. Two of the pipe diversions transfer water out of the Ramapo River at Pompton Lakes. One (Div15) transfers water to the Wanaque Reservoir in the Wanaque River subbasin, and the other (Div16) transfers water to the Oradell Reservoir in the Hackensack River subbasin. The third pipe diversion (Div18) transfers water out of the Pompton River to the Point View Reservoir on Haycock Brook in the subbasin. The fourth pipe diversion (Div17) transfers water from the Point View Reservoir to the Passaic Valley Water Commission at Wayne. The fifth diversion is a dam diversion (Div14), which transfers water from Posts Brook into the Wanaque Reservoir in the Wanaque River subbasin.

The two partial-record stations in the Pompton River subbasin are on Posts Brook (table 6, fig. 7). The Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (01387020), measures the amount of diversion to the Wanaque Reservoir. The Posts Brook below Wanaque diversion near Wanaque, N.J. (01387021), measures streamflow in Posts Brook downstream from the diversion.

There are six flow-reconstruction sites in the Pompton River subbasin (table 7, fig. 7). One site is on Stone House Brook at the outlet of Butler Reservoir, N.J. (Recon32). Two sites are on Posts Brook; one (Recon33) is upstream from the diversion to Wanaque Reservoir, and the other (Recon34) is the diversion. One site is on Haycock Brook at the outlet of Point View Reservoir (Recon36). The remaining two sites are at the streamgages on the Ramapo River at Pompton Lakes, N.J. (Recon35), and on the Pompton River at Pompton Plains, N.J. (Recon37).

Rockaway River, Musconetcong River, and Whippany River

The subbasins of the Rockaway, Musconetcong, and Whippany Rivers are in the western part of the group of reconstruction subbasins (fig. 3). The Rockaway River subbasin contains the following streams: Rockaway River, Beaver Brook, and Stony Brook (fig. 8). Beaver Brook and Stony Brook are tributaries to Rockaway River. Selected features of the Rockaway River subbasin include 2 reservoirs (table 3), 1 pipe diversion (table 4), 3 streamgages (table 5), and 4 flow-reconstruction sites (table 7). The two reservoirs are Boonton Reservoir on the Rockaway River and Splitrock Reservoir on Beaver Brook. The one pipe diversion (Div20) transfers water from the Boonton Reservoir outside the basin to Jersey City for treatment and distribution for use. The three streamgages are on Beaver Brook downstream from the outlet of Splitrock Reservoir, N.J. (01380000); Rockaway River above the Reservoir at Boonton, N.J. (01380500); and Rockaway River below the Reservoir at Boonton, N.J. (01381000). The flow-reconstruction sites are at the streamgage on Beaver Brook (Recon39); the Stony Brook tributary at the outlet of Taylortown Reservoir, N.J. (Recon40); the streamgage on the Rockaway River above the Reservoir at Boonton, N.J. (Recon41); and the streamgage on the Rockaway River below Reservoir at Boonton, N.J. (Recon42).

Selected features of the Musconetcong River subbasin (fig. 8) include Lake Hopatcong (table 3), 1 pipe diversion (table 4), 1 streamgage (table 5), and 1 flow-reconstruction site. The diversion (Div19) was used to transfer water from Lake Hopatcong to the Rockaway River subbasin during 1965–66 and 1980–81. The streamgage is on the Musconetcong River at the outlet of Lake Hopatcong, N.J. (01455500), and at the outlet of the subbasin. The flow-reconstruction site is at the streamgage (Recon38).

Selected features of the Whippany River subbasin (fig. 8) include 2 streamgages (table 5) and 3 flow-reconstruction sites (table 7). The streamgages are on the Whippany River near Morristown, N.J. (01381400), and the Whippany River at Morristown, N.J. (01381500). The flow-reconstruction sites are at the two streamgages on the Whippany River near Morristown, N.J. (Recon44), and at Morristown, N.J.(Recon45), and on Harmony Brook (a tributary to Whippany River) at the outlet of the Clyde Potts Reservoir (Recon43). Storage in Clyde Potts Reservoir was not included in the analysis because no records of storage were available.

Main Stem Passaic River

The Main Stem Passaic River subbasin is the southernmost of the group of reconstruction subbasins (fig. 3), ending at Little Falls, N.J. This subbasin is bounded on the upstream and downstream extents by streamgages (table 5, fig. 9). The following streamgages are at the upstream extents: Pompton River at Pompton Plains, N.J. (01388500); the Rockaway River below Reservoir at Boonton, N.J. (01381000); and the Whippany River at Morristown, N.J. (01381500). The downstream boundary is at the streamgage on the Passaic River at Little Falls, N.J. (01389500). Reaches of the following streams are included in the subbasin: Whippany River, Rockaway River, Pompton River, Canoe Brook, and Passaic River. The first four streams are tributaries of the Passaic River.

Selected features of the Main Stem Passaic River subbasin (fig. 9) include 6 pipe diversions (table 4), 5 streamgages (table 5), and 8 flow-reconstruction sites. The diversions from the Passaic River near Summit, N.J. (Div21), and from Canoe Brook near Summit, N.J. (Div22), remove water for treatment and distribution. Diversions from the Pompton River transfer water to Wanaque Reservoir in the Wanaque River subbasin (Div23), to Oradell Reservoir in the Hackensack River subbasin (Div24); and to the Passaic Valley Water Commission at Wayne (Div25). The diversion at the Passaic River at Little Falls, N.J. (Div26), removes water for treatment and distribution. Records from the following streamgages were included in the analysis: Passaic River near Millington, N.J. (01379000); Passaic River near Chatham, N.J. (01379500); Canoe Brook near Summit, N.J. (01379530); Passaic River at Pine Brook, N.J. (01381900); and Passaic River at Little Falls, N.J. (01389500).

Flow-reconstruction sites are designated at eight locations in the Main Stem Passaic River subbasin (fig. 9, table 7). Three sites are designated at diversions on the Passaic River near Summit (Recon47), Canoe Brook at diversion near Summit (Recon48), and the Passaic River above Beatties Dam at Little Falls (Recon52). Three sites are at the streamgages at Passaic River near Chatham N.J. (Recon46); Passaic River at Pine Brook, N.J. (Recon49); and the Passaic River at Little Falls, N.J. (Recon53). The remaining two sites are on the Passaic River at Two Bridges, N.J. (Recon50), and the Pompton River at Two Bridges, N.J. (Recon51); these sites are just upstream from the junction of the Passaic and Pompton Rivers.

Previous Studies

There have been four reports in which daily reconstructed streamflows in the Passaic River Basin have been determined. Two unpublished reports describe the methods used to reconstruct daily streamflows at sites throughout the Passaic River Basin and use similar methods. Clinton Bogart Associates produced the report, “Documentation of Passaic River Basin daily natural flow data” (Clinton Bogart Associates, written commun., 1982), which presents reconstructed daily streamflows for water years 1920–79 at 14 sites by summing measured streamflows, changes in upstream reservoirs, and upstream surface-water diversions from purveyors. Missing values of reconstructed streamflows at a site were estimated from (1) linear regression between reconstructed streamflows at the site and streamflows at a selected streamgage or (2) from drainage-area adjustment of reconstructed streamflows at a selected streamgage.

Lawler, Matusky & Skelly Engineers produced the report, “Jersey City Municipal Utilities Authority, reports on reservoir storage and safe yield” (Lawler, Matusky, and Skelly Engineers, written commun., 2004), which describes methods used to determine reconstructed streamflows at 10 sites in the Passaic River Basin during water years 1979–93. These methods also were described in a facsimile transmission from Don Distante of Lawler, Matusky & Skelly Engineers to Ashgar Hasan, NJDEP, dated February 19, 1997. Reconstructed flows were determined by (1) summing measured streamflow, changes in reservoir storage, and the amount of surface-water diversions by purveyors leaving the basin, and then (2) subtracting from this sum the amount of water discharged by selected wastewater-treatment plants. Some values at selected sites were determined from drainage-area adjustment of reconstructed flows at other sites.

Dresnack and others (1984) estimated daily reconstructed streamflows at seven sites in the Passaic River Basin during 1921–81. Calculated values were determined by adjusting measured streamflow for reservoir storage changes and surface-water diversions by purveyors. Missing values of daily reconstructed flows at a site were determined using multiple linear regressions between calculated values of reconstructed flows at that site and daily streamflows at selected streamgages.

More recently, monthly and daily reconstructed flows at 34 sites in the basins of the Passaic, Hackensack, and Saddle Rivers were determined by Storck and Nawyn (2001); monthly reconstructed streamflows during water years 1993–96 and daily reconstructed streamflows for May 1, 1995, to October 31, 1995, were determined. Flows were reconstructed by adjusting measured streamflow for surface-water and groundwater withdrawals from the basin (added to streamflow), net surface-water diversion into the basin (subtracted from streamflow), net groundwater diversion into the basin (subtracted from streamflow), changes in reservoir storage (added to streamflow), and wastewater-treatment-plant discharges reduced by the estimated infiltration and inflow into sewer lines (subtracted from streamflow). Missing streamflows were estimated by using either (1) multiple regression to correlate flows at different gages, (2) Maintenance of Variance Extension type 1 (MOVE1) relations (Hirsch, 1982), or (3) drainage-area adjustment.

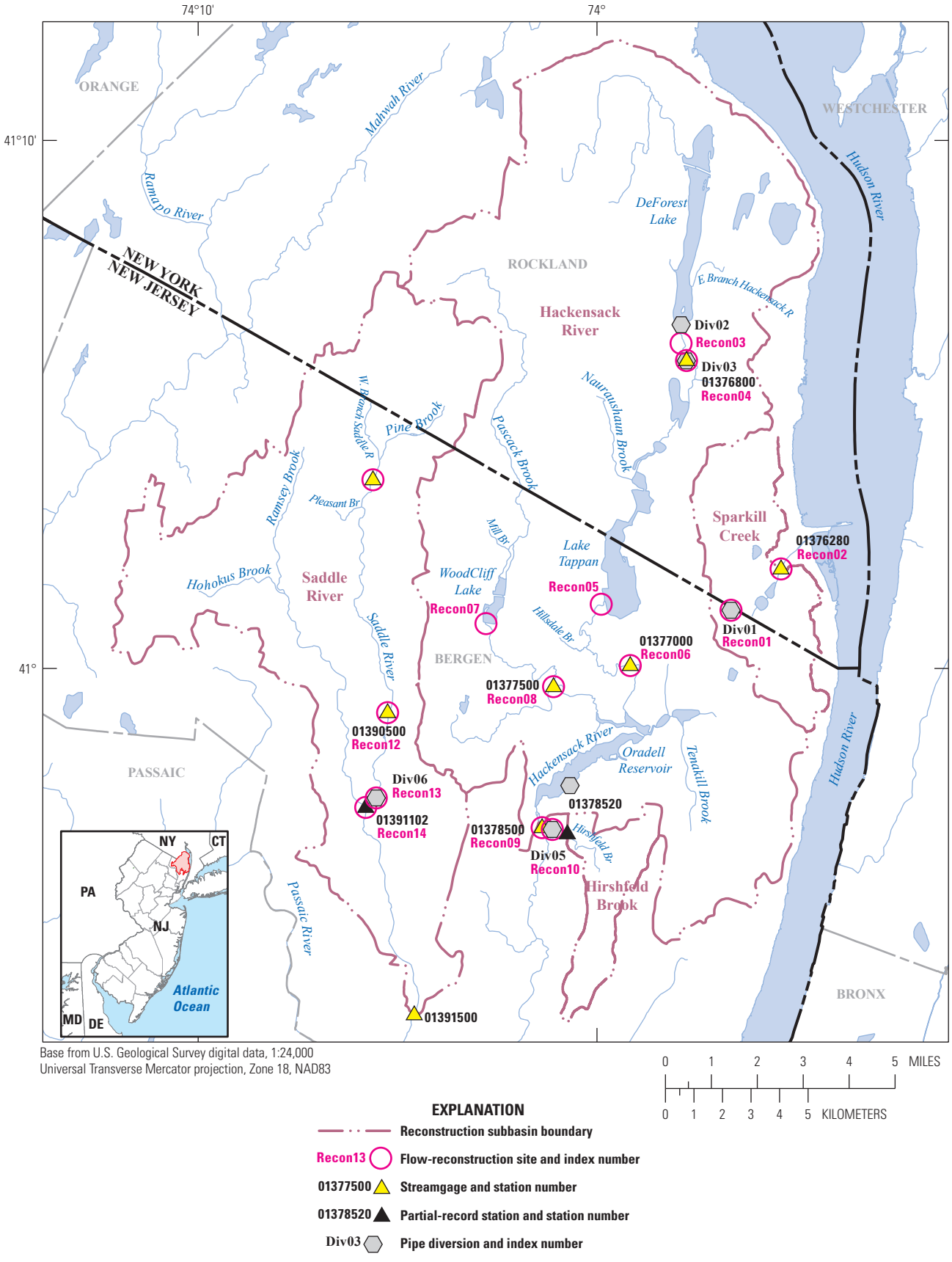

Figure 4. Selected features of the subbasins of the Hackensack River, Saddle River, Hirshfeld Brook, and Sparkill Creek in northern New Jersey and southeastern New York.

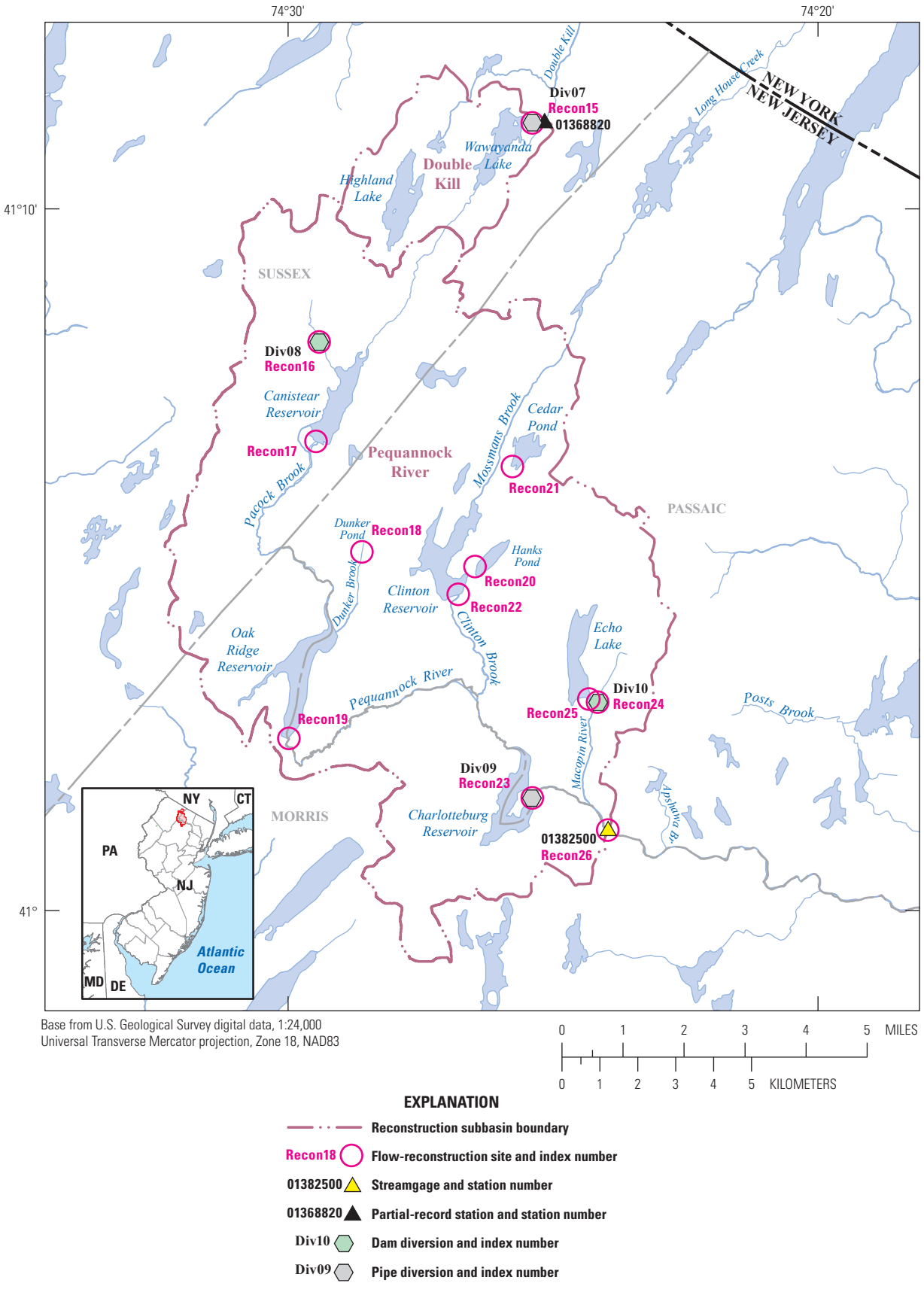

Figure 5. Selected features of the subbasins of the Pequannock River and Double Kill in northern New Jersey and southeastern New York.

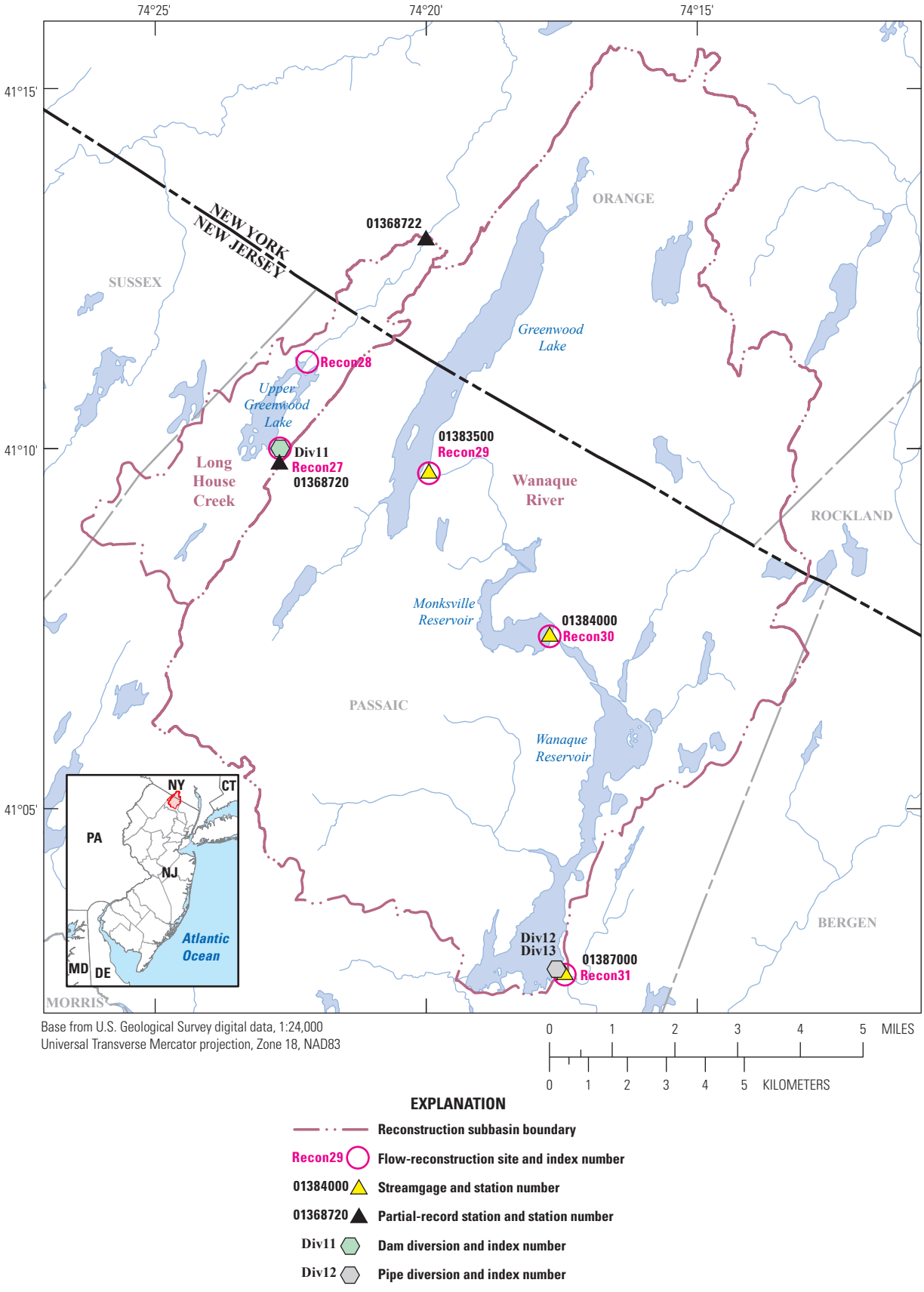

Figure 6. Selected features of the subbasins of the Wanaque River and Long House Creek in northern New Jersey and southeastern New York.

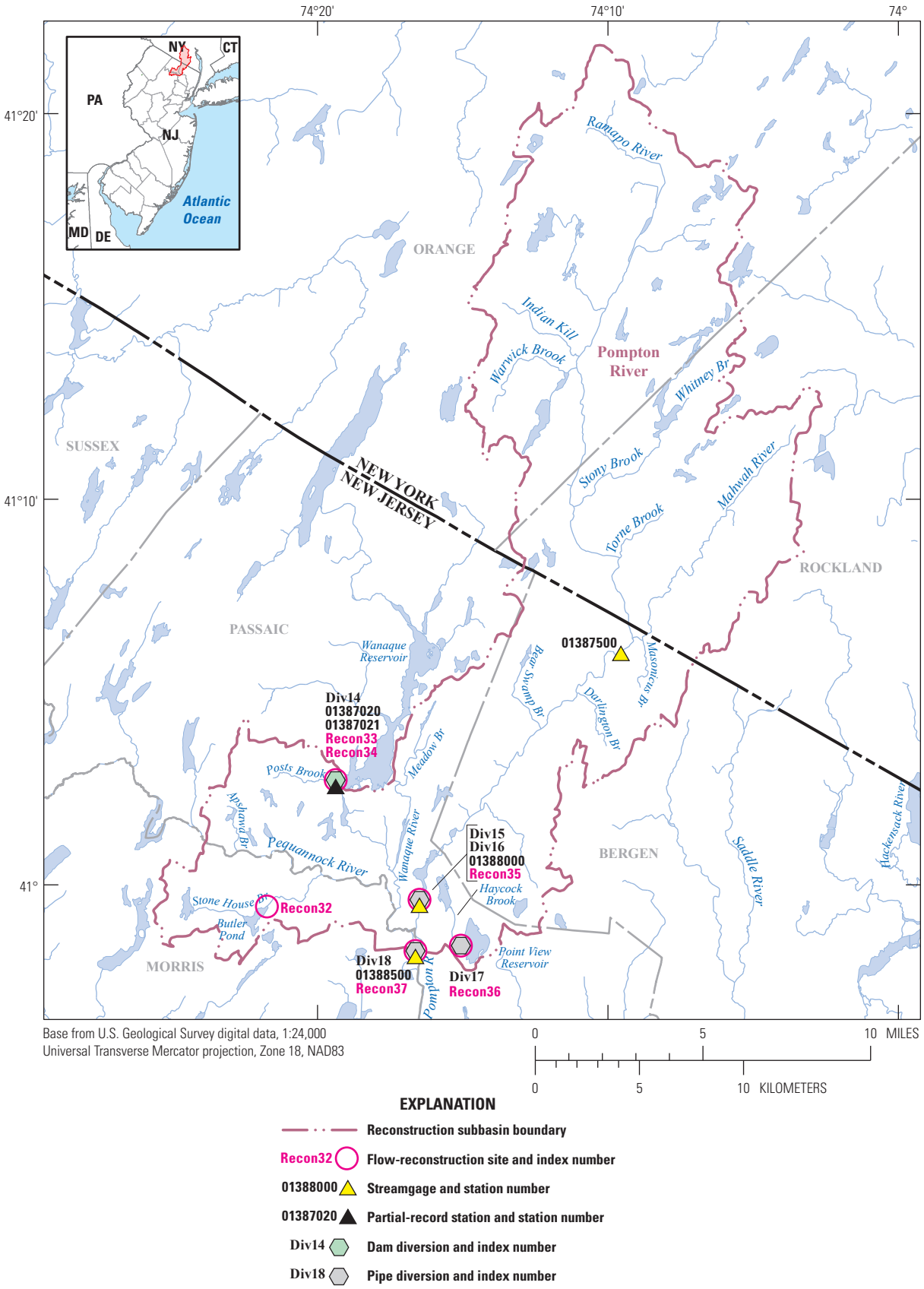

Figure 7. Selected features of the subbasin of the Pompton River in northern New Jersey and southeastern New York.

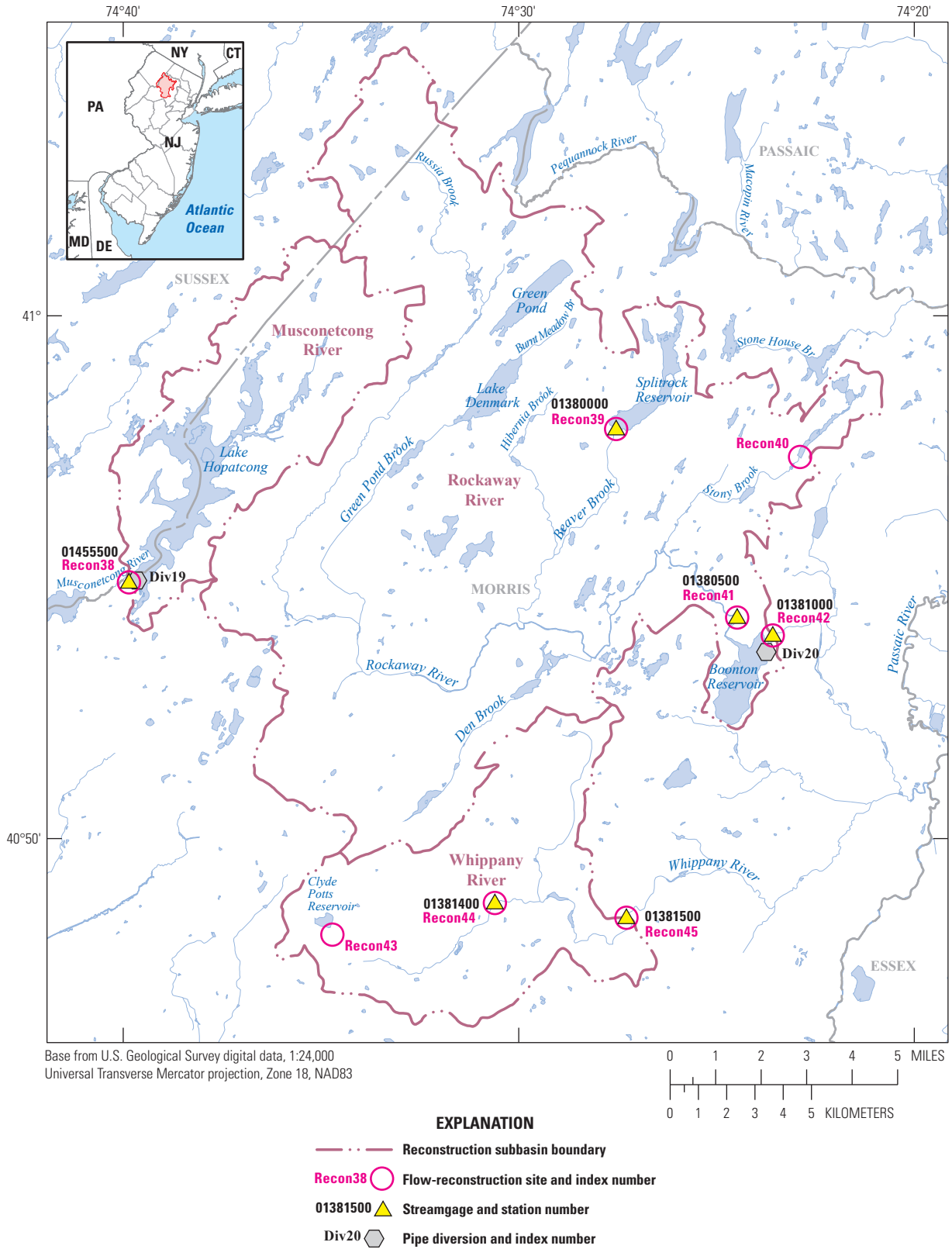

Figure 8. Selected features of the subbasins of the Rockaway River, Musconetcong River, and Whippany River in northern New Jersey.

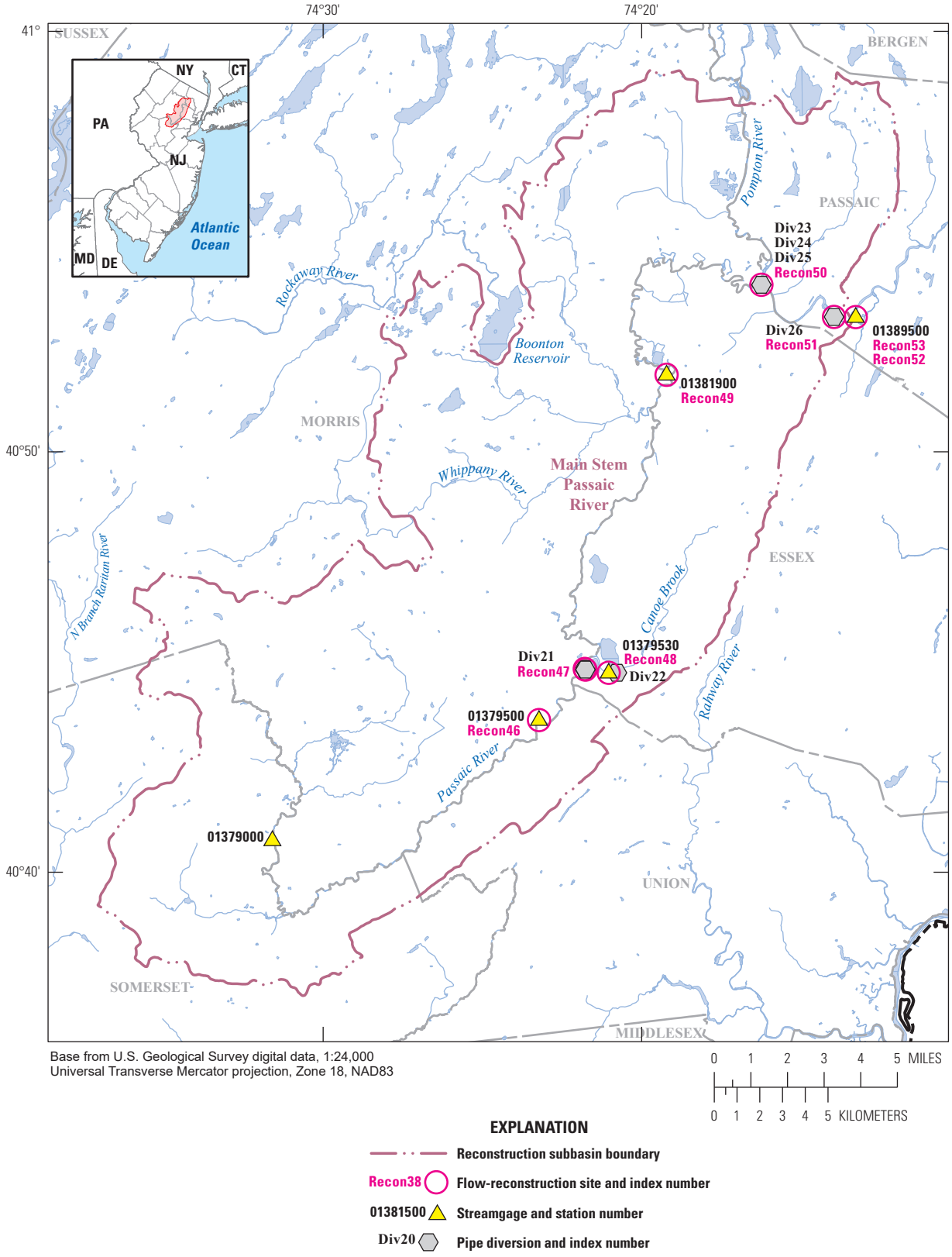

Figure 9. Selected features of the subbasin of the Main Stem Passaic River in northern New Jersey.

Table 3. Description of selected reservoirs in the reconstruction subbasins in northern New Jersey and southeastern New York.

[Latitude and Longitude are in degrees, minutes, seconds; N.J., New Jersey; N.Y., New York; operator is as of 2017; period of record of end-of-month storage includes water years with partial record of monthly storage; USGS, U.S. Geological Survey; NJDEP, New Jersey Department of Environmental Protection]

Reservoir		Location of outlet		Drainage area at outlet (square miles)	Capacity (total unless otherwise indicated) from USGS records unless otherwise indicated (million gallons)	Operator	Calendar year constructed	Period of record of end-of-month storage data through 2010, in water years (source of data)
USGS station name (number)	Short name	Latitude	Longitude					
Hackensack River subbasin								
DeForest Lake at West Nyack, N.Y. (01376700)	DeForest Lake	410622	0735759	27.5	5,670	Suez North America	1956	1956–2010 (New Jersey Geological and Water Survey, 2013)
Lake Tappan at Old Tappan, N.J. (01376950)	Lake Tappan	410106	0740004	49	3,853	Suez North America	1966	1966–2010 (New Jersey Geological and Water Survey, 2013)
Woodcliff Lake at Hillsdale, N.J. (01377450)	Woodcliff Lake	410046	0740257	19.4	871	Suez North America	1905	1930–2010 (New Jersey Geological and Water Survey, 2013)
Oradell Reservoir at Oradell, N.J. (01378480)	Oradell Reservoir	405723	0740146	113	3,507	Suez North America	1922	1923–2010 (New Jersey Geological and Water Survey, 2013)
Pequannock River subbasin								
Canistear Reservoir near Stockholm, N.J. (01382100)	Canistear Reservoir	410640	0742931	6.08	2,407	City of Newark	About 1896	1924–2010 (New Jersey Geological and Water Survey, 2013)
Oak Ridge Reservoir at Oak Ridge, N.J. (01382200)	Oak Ridge Reservoir	410226	0743004	27.3	3,895	City of Newark	1880–92	1924–2010 (New Jersey Geological and Water Survey, 2013)
Clinton Reservoir near Newfoundland, N.J. (01382300)	Clinton Reservoir	410428	0742651	10.5	3,518	City of Newark	1889–92	1924–2010 (New Jersey Geological and Water Survey, 2013)
Charlotteburg Reservoir at Charlotteburg, N.J. (01382380)	Charlotteburg Reservoir	410134	0742529	56.2	[1]2,964	City of Newark	Finished 1961	1961–2010 (New Jersey Geological and Water Survey, 2013)
Echo Lake near Charlotteburg, N.J. (01382400)	Echo Lake	410258	0742425	[2]4.35	[3]1,583	City of Newark	About 1925	1928–2010 (New Jersey Geological and Water Survey, 2013)

Table 3. Description of selected reservoirs in the reconstruction subbasins in northern New Jersey and southeastern New York.—Continued

[Latitude and Longitude are in degrees, minutes, seconds; N.J., New Jersey; N.Y., New York; operator is as of 2017; period of record of end-of-month storage includes water years with partial record of monthly storage; USGS, U.S. Geological Survey; NJDEP, New Jersey Department of Environmental Protection]

Reservoir		Location of outlet		Drainage area at outlet (square miles)	Capacity (total unless otherwise indicated) from USGS records unless otherwise indicated (million gallons)	Operator	Calendar year constructed	Period of record of end-of-month storage data through 2010, in water years (source of data)
USGS station name (number)	Short name	Latitude	Longitude					
Wanaque River subbasin								
Greenwood Lake at Awosting, N.J. (01383000)	Greenwood Lake	410942	0742000	27.1	[4]6,860	New Jersey Department of Environmental Protection	About 1837	1898–1903, 1907–2010, only gage heights prior to 1953 (New Jersey Geological and Water Survey, 2013)
Monksville Reservoir at Monks, N.J. (01384002)	Monksville Reservoir	410721	0741748	40.4	7,000	North Jersey District Water Supply Commission	1988	1987–2010 (New Jersey Geological and Water Survey, 2013)
Wanaque Reservoir at Wanaque, N.J. (01386990)	Wanaque Reservoir	410242	0741743	90.4	29,630	North Jersey District Water Supply Commission	1927	1928–2010 (New Jersey Geological and Water Survey, 2013)
Musconetcong River subbasin								
Lake Hopatcong at Landing, N.J. (01455400)	Lake Hopatcong	405503	0743951	25.3	[4]7,459	New Jersey Department of Environmental Protection	1828; spillway lowered in 1925	1887–2010 (transcription of USGS records and reports)
Rockaway River subbasin								
Splitrock Reservoir near Hibernia, N.J. (01379990)	Splitrock Reservoir	405748	0742735	4.92	3,310	Suez North America	Construction prior to 1925; 1946–48 present dam added	1925–31, 1948–2010 (New Jersey Geological and Water Survey, 2013)
Boonton Reservoir at Boonton, N.J. (01380900)	Boonton Reservoir	405343	0742352	119	[5]8,165	Suez North America	1904	1904–2010 (New Jersey Geological and Water Survey, 2013)

[1]Storage to top of Bascule gate; gate decommissioned 2001. Total capacity without the gate was 2,407 million gallons (Richard Grabowski, NJDEP, written commun., 2017).

[2]Includes Mathews Brook diversion drainage.

[3]Storage may be greater than 1,583 million gallons (Richard Grabowski, NJDEP, oral commun., 2015).

[4]Usable capacity.

[5]Lawler, Matusky & Skelly Engineers (2004). Bascule gates assumed down.

Table 4. Selected surface-water diversion sites in the reconstruction subbasins in northern New Jersey and southern New York.

[n.a., not applicable; latitude and longitude in degrees, minutes, seconds; datum for Latitude and Longitude is the North American Datum of 1983; Pipe is pipe diversions, and Dam is dam diversion as defined in the text; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Selected surface-water diversions		Latitude	Longitude	Drainage area at point of diversion (square miles)	Operator	Form of diversion (diversion is ongoing unless otherwise indicated)	Destination of diverted water (subbasin)	Comment
Index number	Name (station number)							
Sparkill Creek subbasin								
Div01	Sparkill Creek diversion at Northvale, N.J. (01376272)	410058	0735649	5.54	Suez North America	Pipe	Tappan Run, a tributary of Dorotockeys Run and Oradell Reservoir (Hackensack River)	n.a.
Hackensack River subbasin								
Div02	DeForest Lake diversion at West Nyack, N.Y. (01376699)	410622	0735800	27.5	Suez North America	Pipe	Treatment and distribution (n.a.)	n.a.
Div03	Hackensack River diversion at West Nyack, N.Y. (01376790)	410544	0735752	30.7	Village of Nyack, N.Y.	Pipe	Treatment and distribution (n.a.)	Station number revised from 01376810 in water year 2009.
Div04	Oradell Reservoir diversion at Haworth, N.J. (01378478)	405741	0740054	113	Suez North America	Pipe	Treatment and distribution (n.a.)	Prior to May 1990, diversion was taken from just upstream of the continuous-record stream-gage at New Milford (01378500).
Hirshfeld Brook subbasin								
Div05	Hirshfeld Brook diversion at New Milford, N.J. (01378521)	405651	0740121	4.54	Suez North America	Pipe	Oradell Reservoir (Hackensack River)	n.a.
Saddle River subbasin								
Div06	Saddle River diversion at Paramus, N.J. (01390520)	405730	0740546	22.9	Suez North America	Pipe	Musquapsink Brook, a tributary of Pascack Brook and Oradell Reservoir (Hackensack River)	Diverts water in Saddle River between this site and downstream to weir on Saddle River below Hohokus Brook at Paramus (01391102) with a drainage area of 43.3 square miles.
Double Kill subbasin								
Div07	Double Kill diversion from Lake Wawayanda to Cherry Ridge Brook, N.J. (n.a.)	411111	0742524	6.18	New Jersey Department of Environmental Proctection	Pipe (discontinued)	Cherry Ridge Brook which is tributary to Canistear Reservoir (Pequannock River)	Operated 69 days during 1966 and 117 days during 1980-1981.

Table 4. Selected surface-water diversion sites in the reconstruction subbasins in northern New Jersey and southern New York.—Continued

[n.a., not applicable; latitude and longitude in degrees, minutes, seconds; datum for Latitude and Longitude is the North American Datum of 1983; Pipe is pipe diversions, and Dam is dam diversion as defined in the text; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Selected surface-water diversions		Latitude	Longitude	Drainage area at point of diversion (square miles)	Operator	Form of diversion (diversion is ongoing unless otherwise indicated)	Destination of diverted water (subbasin)	Comment
Index number	Name (station number)							
Pequannock River subbasin								
Div08	Pequannock River diversion to Canistear Reservoir near Stockholm, N.J. (n.a.)	410805	0742927	3.08	City of Newark	Dam (discontinued)	Canistear Reservoir (Pequannock River)	According to Tom Koeppel (City of Newark, phone conversation with Robert Reiser, USGS, July 17, 2013), diversion has not operated since 1976.
Div09	Charlotteburg Reservoir diversion at Charlotteburg N.J. (01382370)	410134	0742529	56.2	City of Newark	Pipe	City of Newark, N.J., for treatment and distribution (n.a.)	n.a.
Div10	Mathews Brook diversion near Macopin, N.J. (01382430)	410255	0742415	1.95	City of Newark	Dam	Echo Lake (Pequannock River)	n.a.
Long House Creek subbasin								
Div11	Auxilary outlet of Upper Greenwood Lake at Moe, N.J. (01368720)	410957	0742246	7.24	North Jersey District Water Supply Commission	Dam	Green Brook which is tributary to Greenwood Lake (Wanaque River)	n.a.
Wanaque River subbasin								
Div12	Wanaque Reservoir diversion at Wanaque, N.J. (01386980)	410242	0741743	90.4	North Jersey District Water Supply Commission	Pipe	Treatment and distribution (n.a.)	n.a.
Div13	Wanaque Reservoir diversion to Oradell Reservoir, N.J. (n.a.)	410242	0741743	90.4	North Jersey District Water Supply Commission	Pipe	Oradell Reservoir (Hackensack River)	Latitude. Longitude, and drainage area set to values for Wanaque Reservoir diversion at Wanaque, N.J. (01386980)

Table 4. Selected surface-water diversion sites in the reconstruction subbasins in northern New Jersey and southern New York.—Continued

[n.a., not applicable; latitude and longitude in degrees, minutes, seconds; datum for Latitude and Longitude is the North American Datum of 1983; Pipe is pipe diversions, and Dam is dam diversion as defined in the text; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Selected surface-water diversions		Latitude	Longitude	Drainage area at point of diversion (square miles)	Operator	Form of diversion (diversion is ongoing unless otherwise indicated)	Destination of diverted water (subbasin)	Comment
Index number	Name (station number)							
Pompton River subbasin								
Div14	Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (01387020)	410235	0741936	3.55	North Jersey District Water Supply Commission	Dam	Wanaque Reservoir (Wanaque River)	Diversion from a tributary downstream of the Wanaque Reservoir so that the water goes into reservoir.
Div15	Ramapo River diversion at Pompton Lakes, N.J. (01387990)	405933	0741644	160	North Jersey District Water Supply Commission	Pipe	Wanaque Reservoir (Wanaque River)	n.a.
Div16	Ramapo River diversion to Oradell Reservoir at Pompton Lakes, N.J. (01387991)	405933	0741643	160	North Jersey District Water Supply Commission	Pipe	Oradell Reservoir (Hackensack River)	n.a.
Div17	Point View Reservoir diversion to Passaic Valley Water Commission at Wayne, N.J. (01387959)	405820	0741520	1.89	Passaic Valley Water Commission	Pipe	Passaic Valley Water Compar-ny intake canal at Little Falls (Main Stem Passaic River)	n.a.
Div18	Pompton River diversion at Pompton Plains, N.J., to Point View Reservoir (01388490)	405810	0741655	355	Passaic Valley Water Commission	Pipe	Point View Reservoir (Ramapo River)	n.a.
Musconetcong River subbasin								
Div19	Lake Hopatcong diversion to Rockaway River, N.J. (n.a.)	405503	0743951	25.3	New Jersey Department of Environmental Proctection	Pipe (discontinued)	Rockaway River (Rockaway River)	Operated 66 days during 1965-1966 and 100 days during 1980-1981.
Rockaway River subbasin								
Div20	Boonton Reservoir diversion at Boonton, N.J. (01380800)	405330	0742350	119	Suez North America	Pipe	Jersey City, N.J., for treatment and distribution (n.a.)	n.a.

Table 4. Selected surface-water diversion sites in the reconstruction subbasins in northern New Jersey and southern New York.—Continued

[n.a., not applicable; latitude and longitude in degrees, minutes, seconds; datum for Latitude and Longitude is the North American Datum of 1983; Pipe is pipe diversions, and Dam is dam diversion as defined in the text; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Selected surface-water diversions		Latitude	Longitude	Drainage area at point of diversion (square miles)	Operator	Form of diversion (diversion is ongoing unless otherwise indicated)	Destination of diverted water (subbasin)	Comment
Index number	Name (station number)							
Main stem Passaic River subbasin								
Div21	Passaic River diversion near Summit, N.J. (01379510)	404444	0742154	102	New Jersey American	Pipe	Treatment and distribution (n.a.)	Missing monthly diversions 1922–65 and 1975–78
Div22	Canoe Brook diversion near Summit, N.J. (01379529)	404440	0742112	11	New Jersey American	Pipe	Treatment and distribution (n.a.)	Missing monthly diversions 1922–65 and 1975–78
Div23	Pompton River diversion to Wanaque Reservoir at Two Bridges, N.J. (01388980)	405400	0741615	[1]379.00	North Jersey District Water Supply Commission	Pipe	Wanaque Reservoir (Wanaque River)	n.a.
Div24	Pompton River diversion to Oradell Reservoir at Two Bridges, N.J. (01388981)	405400	0741615	[1]379.00	North Jersey District Water Supply Commission	Pipe	Oradell Reservoir (Hackensack River)	n.a.
Div25	Pompton River diversion to Passaic Valley Water Commission at Two Bridges, N.J. (01388982)	405400	0741615	[1]379.00	Passaic Valley Water Commission	Pipe	Treatment and distribution (n.a.)	n.a.
Div26	Passaic River diversion at Little Falls, N.J. (01389490)	405306	0741405	762	Passaic Valley Water Commission	Pipe	Treatment and distribution (n.a.)	n.a.

[1]Under low-flow conditions, the diversion on the Pompton River at Two Bridges, N.J., can pump water out of the Passaic River at Two Bridges, N.J., as well as out of the Pompton River. The Passaic River at this point has a drainage area of 361 square miles.

Table 5. Periods of records for observed streamflows at selected streamgages in the reconstruction subbasins in northern New Jersey and southeastern New York.

[Latitude and longitude in degrees, minutes, seconds; datum for latitude and longitude is North American Datum of 1983; USGS, U.S. Geological Survey]

Streamgage					Period of record for observed streamflow data used in this report, in water years; record is complete unless otherwise indicated			Streamgage was used to disaggregate monthly reconstructed streamflows
Station number	USGS station name	Latitude	Longitude	Drainage area (square miles)	Published data from USGS	Furnished or unpublished data from the records of the New Jersey Water Science Center of the USGS	Monthly streamflows estimated from records of other streamgages[1]	
					Sparkill Creek subbasin			
01376280	Sparkill Creek at Sparkill, N.Y.	410144	0735532	10.7	1960–78 incomplete	n.a.	n.a.	No
					Hackensack River subbasin			
01376800	Hackensack River at West Nyack, N.Y.	410544	0735752	30.7	1959–2010 incomplete	n.a.	n.a.	No
01377000	Hackensack River at Rivervale, N.J.	405957	0735921	58	1942–2010	n.a.	n.a.	No
01377500	Pascack Brook at Westwood, N.J.	405934	0740116	29.6	1935–2010	n.a.	n.a.	No
01378500	Hackensack River at New Milford, N.J.	405654	0740136	113	1922–2010	n.a.	n.a.	No
					Saddle River subbasin			
01390450	Saddle River at Upper Saddle River, N.J.	410331	0740544	10.9	2004–2010	n.a.	1955–2003 incomplete	No
01390500	Saddle River at Ridgewood, N.J.	405906	0740526	21.6	1955–2010 incomplete	n.a.	n.a.	No
01391102	Saddle River below Hohokus Brook at Paramus, N.J.	405719	0740559	43.3	2013–2014	n.a.	1924–2010	No
01391500	Saddle River at Lodi, N.J.	405325	0740450	54.6	1924–2014	n.a.	n.a.	Yes
					Pequannock River subbasin			
01382500	Pequannock River at Macopin Intake Dam, N.J.	410106	0742404	63.7	1923–2010 incomplete	n.a.	n.a.	No
					Wanaque River subbasin			
01383500	Wanaque River at Awosting, N.J.	410937	0742001	27.1	1922–2010	n.a.	n.a.	Yes
01384000	Wanaque River at Monks, N.J.	410721	0741749	40.4	1935–1985 incomplete	n.a.	n.a.	Yes
01387000	Wanaque River at Wanaque, N.J.	410239	0741735	90.4	1922–2010	n.a.	n.a.	No

Table 5. Periods of records for observed streamflows at selected streamgages in the reconstruction subbasins in northern New Jersey and southeastern New York.—Continued

[Latitude and longitude in degrees, minutes, seconds; datum for latitude and longitude is North American Datum of 1983; USGS, U.S. Geological Survey]

Streamgage					Period of record for observed streamflow data used in this report, in water years; record is complete unless otherwise indicated			Streamgage was used to disaggregate monthly reconstructed streamflows
Station number	USGS station name	Latitude	Longitude	Drainage area (square miles)	Published data from USGS	Furnished or unpublished data from the records of the New Jersey Water Science Center of the USGS	Monthly streamflows estimated from records of other streamgages[1]	
Pompton River subbasin								
01387500	Ramapo River near Mahwah, N.J.	410553	0740946	120	1923–2010	n.a.	n.a.	No
01388000	Ramapo River at Pompton Lakes, N.J.	405931	0741648	160	1922–2010	n.a.	n.a.	Yes
01388500	Pompton River at Pompton Plains, N.J.	405811	0741655	355	[2]n.a.	n.a.	1923–2010 incomplete	No
Musconetcong River subbasin								
01455500	Musconetcong River at outlet of Lake Hopatcong, N.J.	405502	0743956	25.3	1928–2010 incomplete	n.a.	n.a.	No
Rockaway River subbasin								
01380000	Beaver Brook at outlet of Splitrock Reservoir, N.J.	405747	0742736	4.92	n.a.	1976–1989 incomplete	n.a.	No
01380500	Rockaway River above Reservoir at Boonton, N.J.	405410	0742435	116	1938–2010	n.a.	n.a.	Yes
01381000	Rockaway River below Reservoir at Boonton, N.J.	405349	0742341	119	1922–2010	n.a.	n.a.	No
Whippany River subbasin								
01381400	Whippany River near Morristown, N.J.	404844	0743043	14	1995–2010 incomplete	n.a.	n.a.	No
01381500	Whippany River at Morristown, N.J.	404826	0742725	29.4	1922–2010	n.a.	n.a.	Yes
Main Stem Passaic River subbasin								
01379000	Passaic River near Millington, N.J.	404048	0743144	55.4	1922–2010	n.a.	n.a.	Yes
01379500	Passaic River near Chatham, N.J.	404334	0742323	100	1938–2010	n.a.	1922–1937	Yes
01379530	Canoe Brook near Summit, N.J.	404440	0742113	11	2002–2010	1966–2001 incomplete	n.a.	No
01381900	Passaic River at Pine Brook, N.J.	405145	0741918	349	[3]2006–2010	n.a.	n.a.	No
01389500	Passaic River at Little Falls, N.J.	405305	0741334	762	1922–2010	n.a.	n.a.	Yes

[1]Methods given in appendix 1.

[2]Streamflows for this gage were not retrieved because of inconsistencies with the model at medium and high flows.

[3]Streamflows for this gage during water years 1980-2005 were not retrieved because of difficulties in incorporating variable backwater into streamflows during this period.

Table 6. Description of selected partial-record stations in the reconstruction subbasins in northern New Jersey and southeastern New York.

[Latitude and longitude in degrees, minutes, seconds; NAD 27, North American Datum of 1927; NAD 83, North American Datum of 1983; USGS, U.S. Geological Survey]

USGS station number	USGS station name (streamflow is diversion if so indicated)	Location			Drainage area, in square miles)	Discrete streamflow measurements included in this study			Daily reconstructed flows at indicated site are estimated from discrete flows at partial-record station (reconstruction site index number)
		Latitude	Longitude	Horizontal datum		Period, in water years	Number of streamflow measurements	Purpose of measurements	
Hirshfeld Brook subbasin									
01378520	Hirshfeld Brook at New Milford, N.J.	405649	740059	NAD 83	4.54	1965–2010	33	Define characteristics of low streamflows	(Recon10) Hirshfeld Brook at diversion at New Milford, N.J.
Double Kill subbasin									
01368820	Double Kill at Wawayanda, N.J.	411113	742512	NAD 83	6.46	1998–2012	58	Define streamflow at times of water-quality samples	(Recon15) Double Kill at outlet of Wawayanda Lake at Wawayanda, N.J.
Long House Creek subbasin									
01368720	Auxiliary outlet of Upper Greenwood Lake at Moe, N.J. (diversion)	410957	742246	NAD 83	n.a.	1975–1980	29	Define characteristics of low streamflows	(Recon27) Auxiliary outlet of Upper Greenwood Lake at Moe, N.J.
01368722	Long House Creek below Cascade Lake, N.Y.	411253	742002	NAD 27	8.33	1973–1976	18	Define characteristics of low streamflows	(Recon28) Long House Creek at outlet of Upper Greenwood Lake, N.J.
Pompton River subbasin									
01387020	Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (diversion)	410235	741936	NAD 83	[1]3.55	1935–2014	56	Define characteristics of low streamflows	(Recon33) Posts Brook above Wanaque diversion near Wanaque, N.J. and (Recon34) Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J.
01387021	Posts Brook below Wanaque diversion near Wanaque, N.J.	410235	741938	NAD 83	3.55	2005–2014	19	Define characteristics of low streamflows	(Recon33) Posts Brook above Wanaque diversion near Wanaque, N.J.

[1]Drainage area is that of the station on Posts Brook below Wanaque diversion near Wanaque, N.J. (01387021).

Table 7. Description of flow-reconstruction sites in the reconstruction subbasins in northern New Jersey and southeastern New York.

[Latitude and longitude in degrees, minutes, seconds; drainage area, in square miles; datum for latitude and longitude is North American Datum of 1983; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey; n.a., not applicable]

Index number	Name	USGS station number at site	Selected site features[1]	Latitude	Longitude	Drainage area
			Hackensack River subbasin			
Recon03	Hackensack River at outlet of DeForest Lake at West Nyack, N.Y.	n.a.	Outlet of reservoir and point of diversion	410622	735759	27.5
Recon04	Hackensack River at West Nyack, N.Y.	01376800	Streamgage and point of pipe diversion	410544	735752	30.7
Recon05	Hackensack River at outlet of Lake Tappan at Old Tappan, N.J.	n.a.	Outlet of reservoir	410106	740004	49
Recon06	Hackensack River at Rivervale, N.J.	01377000	Streamgage	405957	735921	58
Recon07	Pascack Brook at Woodcliff Lake outlet at Hillsdale, N.J.	01377451	Outlet of reservoir	410043	740253	19.6
Recon08	Pascack Brook at Westwood, N.J.	01377500	Streamgage	405934	740116	29.6
Recon09	Hackensack River at New Milford, N.J.	01378500	Outlet of reservoir, streamgage, and point of pipe diversion	405654	740136	113
			Saddle River subbasin			
Recon11	Saddle River at Upper Saddle River, N.J.	01390450	Streamgage	410331	740544	10.9
Recon12	Saddle River at Ridgewood, N.J.	01390500	Streamgage	405906	740526	21.6
Recon13	Saddle River below diversion at Paramus, N.J.	01390530	Point of pipe diversion[2]	405730	740547	23
Recon14	Saddle River below Hohokus Brook at Paramus, N.J.	01391102	Point of pipe diversion[2]	405719	740559	43.3
			Hirshfeld Brook subbasin			
Recon10	Hirshfeld Brook at diversion at New Milford, N.J.	n.a.	Point of pipe diversion	405651	740121	4.62
			Sparkill Creek subbasin			
Recon01	Sparkill Creek at diversion at Northvale, N.J.	n.a.	Point of pipe diversion	410058	735649	5.54
Recon02	Sparkill Creek at Sparkill, N.Y.	01376280	Streamgage (discontinued)	410144	735534	10.7
			Double Kill subbasin			
Recon15	Double Kill at outlet of Wawayanda Lake at Wawayanda, N.J.	n.a.	Outlet of reservoir and point of discontinued pipe diversion	411111	0742524	6.17
			Pequannock River subbasin			
Recon16	Pequannock River diversion to Canistear Reservoir near Vernon, N.J.	n.a.	Point of dam diversion	410805	0742927	3.08
Recon17	Pacock Brook at outlet of Canistear Reservoir near Stockholm, N.J.	n.a.	Outlet of reservoir	410640	0742931	6.08
Recon18	Peqannock River tributary at outlet of Dunker Pond, N.J.	n.a.	Outlet of reservoir	410505	0742840	2.72
Recon19	Pequannock River at Oak Ridge, N.J.	01382210	Outlet of reservoir	410223	0743006	27.4
Recon20	Tributary to Clinton Reservoir at outlet of Hanks Pond, N.J.	n.a.	Outlet of reservoir	410452	0742632	0.73

Table 7. Description of flow-reconstruction sites in the reconstruction subbasins in northern New Jersey and southeastern New York.—Continued

[Latitude and longitude in degrees, minutes, seconds; drainage area, in square miles; datum for latitude and longitude is North American Datum of 1983; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey; n.a., not applicable]

Index number	Name	USGS station number at site	Selected site features[1]	Latitude	Longitude	Drainage area
			Pequannock River subbasin—Continued			
Recon21	Tributary to Clinton Reservoir at outlet of Cedar Pond, N.J.	n.a.	Outlet of reservoir	410617	0742549	0.86
Recon22	Clinton Brook at outlet of Clinton Reservoir near Newfoundland, N.J.	n.a.	Outlet of reservoir	410428	0742651	10.5
Recon23	Pequannock River at Charlotteburg, N.J.	01382381	outlet of reservoir and point of pipe diversion	410136	0742528	56.2
Recon24	Mathews Brook diversion near Macopin, N.J.	01382430	Point of dam diversion	410255	0742420	1.95
Recon25	Macopin River at Echo Lake, N.J.	01382410	Outlet of reservoir	410252	0742424	4.42
Recon26	Pequannock River at Macopin Intake Dam, N.J.	01382500	Streamgage	410106	0742404	63.7
			Long House Creek subbasin			
Recon27	Auxiliary outlet of Upper Greenwood Lake at Moe, N.J.	01368720	Dam diversion	410957	0742246	n.a.
Recon28	Long House Creek at outlet of Upper Greenwood Lake, N.J.	01368721	Outlet of reservoir	411111	0742214	7.24
			Wanaque River subbasin			
Recon29	Wanaque River at outlet of Greenwood Lake at Awosting, N.J.	01383500	Streamgage and outlet of reservoir	410942	0742000	27.1
Recon30	Wanaque River at outlet of Monksville Reservoir at Monks, N.J.	01384000	Streamgage (discontinued) and outlet of reservoir	410721	0741749	40.4
Recon31	Wanaque River at outlet of Wanaque Reservoir at Wanaque, N.J.	01387000	Outlet of reservoir, streamgage, and point of pipe diversion	410239	0741735	90.4
			Pompton River subbasin			
Recon32	Stone House Brook at outlet of Butler Reservoir, N.J.	n.a.	Outlet of reservoir, point of pipe diversion	405924	0742158	5.34
Recon33	Posts Brook above Wanaque diversion near Wanaque, N.J.	01387019	Point of dam diversion	410236	0741940	3.55
Recon34	Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J.	01387020	Dam diversion	410235	0741936	n.a.
Recon35	Ramapo River at Pompton Lakes, N.J.	01388000	Streamgage	405931	0741648	160
Recon36	Haycock Brook at outlet of Point View Reservoir near Pompton Plains, N.J.	n.a.	Outlet of reservoir and point of pipe diversion	405820	0741520	1.89
Recon37	Pompton River at Pompton Plains, N.J.	01388500	Streamgage	405811	0741655	355
			Musconetcong River subbasin			
Recon38	Musconetcong River at outlet of Lake Hopatcong, N.J	01455500	Outlet of reservoir and site of streamgage,	405502	0743956	25.3

Table 7. Description of flow-reconstruction sites in the reconstruction subbasins in northern New Jersey and southeastern New York.—Continued

[Latitude and longitude in degrees, minutes, seconds; drainage area, in square miles; datum for latitude and longitude is North American Datum of 1983; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey; n.a., not applicable]

Index number	Name	USGS station number at site	Selected site features[1]	Latitude	Longitude	Drainage area
			Rockaway River subbasin			
Recon39	Beaver Brook at outlet of Splitrock Reservoir near Hibernia, N.J.	01380000	Record of daily discrete streamflows (discontinued) and outlet of reservoir	405747	0742736	4.92
Recon40	Stony Brook tributary at outlet of Taylortown Reservoir, N.J.	n.a.	Outlet of reservoir	405713	0742258	2.18
Recon41	Rockaway River above Reservoir at Boonton, N.J.	01380500	Streamgage	405410	0742435	116.00
Recon42	Rockaway River below Reservoir at Boonton, N.J.	01381000	Streamgage, point of pipe diversion, and outlet of reservoir	405349	0742341	119
			Whippany River subbasin			
Recon43	Harmony Brook at outlet of Clyde Potts Reservoir near Brookside, N.J.	n.a.	Outlet of reservoir	404828	0743449	2.06
Recon44	Whippany River near Morristown, N.J.	01381400	Streamgage	404844	0743043	14
Recon45	Whippany River at Morristown, N.J.	01381500	Streamgage	404826	0742725	29.4
			Main Stem Passaic River subbasin			
Recon46	Passaic River near Chatham, N.J.	01379500	Streamgage	404334	0742323	100
Recon47	Passaic River at diversion near Summit, N.J.	n.a.	Point of pipe diversion	404444	0742154	102
Recon48	Canoe Brook at diversion near Summit, N.J.	01379530	Streamgage and point of pipe diversion	404440	0742113	11
Recon49	Passaic River at Pine Brook, N.J.	01381900	Streamgage	405145	0741918	349
Recon50	Passaic River at Two Bridges, N.J.	01382000	At junction with Pompton River	405350	0741622	361
Recon51	Pompton River at Two Bridges, N.J.	01389000	At junction with Passaic River	405352	0741621	379
Recon52	Passaic River above Beatties Dam at Little Falls, N.J.	01389492	Point of pipe diversion	405304	0741404	762
Recon53	Passaic River at Little Falls, N.J.	01389500	Streamgage	405305	0741334	762

[1] For this report, all diversions from reservoirs are considered to be located at the reservoir outlet.

[2] The surface-water diversion at Paramus withdraws water from the Saddle River reach downstream to the junction with Hohokus Brook.

Methods

Methods are presented in three sections: "Assembling Information Needed to Determine Monthly Reconstructed Flows," "Determination of Monthly Reconstructed Flows," and "Determination of Daily Reconstructed Flows from Monthly Reconstructed Flows." In these sections, the methods are presented in general terms. More detailed information about the application of these methods specific to each flow-reconstruction site is provided in appendixes 1–4.

Assembling Information Needed to Determine Monthly Reconstructed Flows

Assembled information consisted of observed streamflows, rates of transfer for selected diversions, and changes in reservoir storage. Measured and estimated values were included.

Monthly Observed Streamflow at Streamgages

Published daily observed streamflows at selected streamgages (table 5) were retrieved from the USGS National Water Information System (NWIS) website at https://waterdata.usgs.gov/usa/nwis/sw. Monthly observed streamflows were calculated from daily values.

Some published streamflows reported by the USGS were not used in this report. The streamflows at Pompton River at Pompton Plains, N.J. (01388500), for water years 1940–2010 were not used because of uncertainties in the reported medium and high flows; this streamgage is in the Pompton River subbasin. The streamflows at Passaic River at Pine Brook, N.J. (01381900), for water years 1979–2005 were not used because of difficulties in incorporating variable backwater into streamflows during this period; this streamgage is in the Main Stem Passaic River subbasin.

Selected monthly observed streamflows at four streamgages in the Saddle River, Pompton River, and Main Stem Passaic River subbasins (table 5) were estimated from published monthly observed streamflows at other streamgages in order to complete the periods of record for the study period 1922–2010. Specific details of the estimation calculations are given in appendix 1. In this report, the term "observed" is used to indicate true streamflow conditions, which include water withdrawals and effects of reservoirs, and not necessarily values measured by gaging equipment. Therefore, "estimated observed" data are those that are estimated but which include effects of water use. The goal was to fill in as much record as possible with simple drainage area adjustments of gaged streamflow, rather than estimating after reconstruction.

Monthly observed flows at one streamgage were calculated from unpublished USGS records of daily observed streamflows (table 5) obtained from the New Jersey Water Science Center of the USGS. Records for Canoe Brook near Summit, N.J. (01379530), for water years 1966–2001 are incomplete and unpublished; this streamgage is in the Main Stem Passaic River subbasin. Published streamflow records began in 2002. Prior to that, computing streamflow proved difficult because of backwater conditions from the Passaic River and surface-water withdrawals from the streamgage pool. The backwater effects would result in negative and zero flows for short periods of time. For periods of non-backwater, the record is considered to be valid. For the purposes of this investigation, the unpublished record is considered to be adequate. The use of the Canoe Brook data does not imply approval by USGS standards.

Estimates of observed streamflows at Beaver Brook at outlet of Splitrock Reservoir, N.J. (01380000), were determined from once-daily stage measurements provided to the USGS during water years 1976–89 by Jersey City and a stage-discharge rating developed by USGS; methods used to calculate monthly streamflows in Beaver Brook are presented in appendix 2. The Beaver Brook streamgage is in the Rockaway River subbasin. Records were not published or otherwise approved by USGS because (1) only once-daily readings would not necessarily indicate a mean reading for the day, and (2) those readings were not collected by USGS. Despite these substandard conditions for flow determination, this record is considered to be adequate for the purposes of this analysis and provides the best flow data available at this site without the use of complex empirical or mathematical models for estimation. The use of the Beaver Brook records in this investigation does not imply approval by USGS standards.

Daily and Monthly Observed Streamflows at Partial-Record Stations

Available discrete measurements of streamflow at six partial-record stations (table 6) were retrieved from the NWIS website. Measurements at four stations were retrieved for water years 1922–2010; measurements at one station were retrieved for water years 1922–2012 and, at another station, for water years 1922–2014.

Daily and monthly observed streamflows at each partial-record station were estimated from MOVE1 relations between discrete streamflows at the partial-record station and daily observed streamflows at each index gage (appendix 3). Monthly observed flows at the partial-record stations were then calculated from daily flows.

Rates of Monthly Transfer at Surface-Water Diversions

Monthly rates of transfer for the selected surface-water diversions (table 4) were either reported or estimated. Sources of reported rates of transfer in pipe diversions are listed in

table 8; most reported values were from the compilation by the New Jersey Geological and Water Survey (2013). The North Jersey District Water supply commission uses three separate pipe diversions (Div13, Div16, and Div24) to transfer water to the Oradell Reservoir. Although the total water transferred to Oradell Reservoir was available from the compilation, the rates for each individual diversion were not. Rates of transfer for the three pipe diversions to Oradell Reservoir (Div13, Div16, and Div24) were therefore estimated, as described in appendix 4. Also missing from the compilation were rates of transfer for two New Jersey American Water Company diversions at Summit (Div21 and Div22) prior to 1978. Data for the period 1965–73 were provided by NJDEP and are available in the data release associated with this report (Hickman, 2018).

Monthly rates of transfer for all dam diversions were estimated. Monthly rates of transfer for some diversions were estimated from monthly observed streamflows estimated for partial-record stations (table 6). Monthly rates of transfer for the remaining dam diversions were estimated from drainage-area adjustment of reconstructed flows at selected sites.

Changes in Reservoir Storage

Changes in reservoir storage were determined from reported end-of-month storage at selected reservoirs (table 3). Values of end-of-month storage for months prior to the construction of each reservoir were set to zero.

Determination of Monthly Reconstructed Flows

Monthly reconstructed flows were determined for sites at which a record of monthly streamflow was either measured for a streamgage at the site (observed streamflow) or estimated from the record of streamflow for a nearby streamgage (estimated observed streamflow). In the following discussions, "observed flows" include those from a streamgage and those that were estimated. These methods were not applied to any site at which the monthly reconstructed flows were estimated from discrete streamflow measurements at partial-record stations.

In general, three methods were used to determine monthly reconstructed flows at a site. First, monthly reconstructed flows were calculated by adjusting monthly observed streamflow for changes in reservoir storage and diversions. Second, monthly reconstructed flows not calculated because of insufficient data were estimated from relations between (1) selected calculated monthly reconstructed flows and (2) monthly flows at each index gage. Third, at some sites, monthly reconstructed flows were determined from corresponding values at other sites, by summing upstream reconstructed flows and (or) using a drainage area adjustment on appropriate nearby reconstructed flows.

Calculation and Estimation of Monthly Reconstructed Flows at Sites with Monthly Streamflow

For each reconstruction site with a record of monthly streamflow, a monthly streamflow adjustment was determined for each month by summing (1) the rate of diversion out of the site drainage area minus the rate of diversion into it and (2) the change in monthly reservoir storage within the drainage area (eq. 1). The monthly reconstructed streamflow was calculated by summing monthly observed streamflow and streamflow adjustment (eq. 2).

$$mReconXXadj = (Div_{out} - Div_{in}) + DelStorage \quad (1)$$

$$ReconXX = mAAAAAAAA + mReconXXadj \quad (2)$$

where

$mReconXXadj$	is	monthly streamflow adjustment at selected reconstruction site, in cubic feet per second;
Div_{out}	is	monthly surface-water diversions out of drainage area of the streamgage, in cubic feet per second;
Div_{in}	is	monthly surface-water diversions into drainage area of the streamgage, in cubic feet per second;
$DelStorage$	is	sum of changes in monthly storage of selected reservoirs in the drainage area of the streamgage, in cubic feet per second;
$mAAAAAAAA$	is	monthly observed streamflow at streamgage with station number *AAAAAAAA*, in cubic feet per second; and
$ReconXX$	is	calculated monthly reconstructed streamflow at reconstruction site, *XX*, in cubic feet per second.

Monthly reconstructed flows could not be calculated for each site for all months of the period of study, usually because of missing records of monthly observed streamflow. Some records of reservoir storage and pipe diversions also were incomplete.

For a few sites, some values of calculated monthly reconstructed flows were determined by setting some missing values of diversion or change in reservoir storage to zero. This was done only if the missing term appeared to be a small part of the reconstructed flow. Instances when this was done are mentioned in the section "Application of Methods to Flow-Reconstruction Sites in Each Subbasin."

Missing values of monthly reconstructed flows at a selected site were estimated from relations between selected

calculated monthly reconstructed flows and monthly observed flows at each index gage. The form of each relation is given in equation 3.

$$mReconXX\_calc = (mIndex \times slope) + intercept \quad (3)$$

where,

mReconXX_calc is calculated monthly reconstructed streamflow, in cubic feet per second;
mIndex is monthly observed streamflow at index gage, in cubic feet per second;
slope is equation slope, unitless; and
intercept is equation intercept, in cubic feet per second.

Periods of missing values of monthly reconstructed flows for each site were identified (table 9). As many as three periods of missing values were designated for each site.

For each period of missing monthly reconstructed flows, a period of selected calculated monthly reconstructed flows was identified (table 9). Relations to estimate the missing values were developed between these selected calculated values and monthly observed streamflows for each index gage. The period of calculated values was selected to be as close in time as possible to the period of missing values and to consist of up to 240 months.

It was found that a single equation did not sufficiently represent the relation between each of the flow-reconstruction sites and the index gage for the full range of monthly flows. An obvious difference in the relation was observed when flows at the index gage were less than 50 cubic feet per second (ft^3/s). The relation was found to be further improved by separating the monthly data into classes on the basis of the ratio of maximum daily mean flow to daily mean flow on the first day of the month. Each month of the period of study was therefore divided into four hydrologic classes on the basis of the record of daily observed streamflow at the index gage Pequest River at Pequest, N.J. (01445500). For most sites, missing monthly reconstructed flows in each period were then estimated from four separate relations between selected calculated monthly reconstructed flows and monthly observed streamflows at each index gage (table 9), based on the defined class. Each class was defined by (1) the daily streamflow on the first day of the month and (2) the ratio of the maximum daily streamflow to the streamflow on the first day.

- Class 1:
  - Streamflow on first day of month is less than or equal to 50 ft^3/s.
  - Ratio of maximum daily streamflow in the month to streamflow on first day is less than or equal to 2.
- Class 2:
  - Streamflow on first day of month is less than or equal to 50 ft^3/s.
  - Ratio of maximum daily streamflow in the month to streamflow on first day is greater than 2.
- Class 3:
  - Streamflow on first day of month is greater than 50 ft^3/s.
  - Ratio of maximum daily flow in the month to streamflow on first day is less than or equal to 1.
- Class 4:
  - Streamflow on first day of the month is greater than 50 ft^3/s.
  - Ratio of maximum daily flow in the month to streamflow on first day is greater than 1.

For a few periods of missing values at selected sites, there were far fewer than 240 months of calculated total reconstructed flows to create the relations. For these, only one relation was developed between the calculated values and monthly observed streamflows at each index gage.

For the relations of the monthly reconstructed flow sites versus index gages for each of the defined classes, values of slope and intercept in each equation were determined by use of the Maintenance of Variance Extension Type 1 (Hirsch, 1982). This linear regression method, known as MOVE1, is described in appendix 5. Values of slope and intercept for each equation are presented in the data release (Hickman, 2018).

Estimated values of monthly reconstructed flows were those determined from the MOVE1 equations derived using monthly observed flows in the Paulins Kill at Blairstown, N.J. (01443500). Missing values during water year 1977 were filled in with the corresponding values estimated from the MOVE1 equations using observed monthly streamflow in the Pequest River at Pequest, N.J. (01445500).

Estimation of Monthly Reconstructed Flows from Corresponding Values at Other Sites

At a few sites, monthly reconstructed flows were determined from monthly reconstructed flows at other sites using one of two methods. For the first method, monthly reconstructed flows at one site were estimated from a drainage-area adjustment of corresponding flows at a second site.

The second method was to determine monthly reconstructed flows at selected sites by calculating and estimating "sectional" monthly reconstructed flows occurring between sites of known flow. These sectional flows can be thought of as local inflow in the intervening area between sites in a section of the subbasin. These sectional flows were needed specifically for the lower part of the Main Stem Passaic River subbasin, in the areas downstream from Pompton Plains and Chatham to Little Falls, N.J. (fig. 9). Here, the local contributing flow per square mile is different than upstream in the basin because it can be considerably affected by seasonal evapotranspiration

rates from wetlands and effects of variable backwater as the Pompton River joins the Passaic River at Two Bridges, N.J. Sectional flows also were used for estimates in the relatively isolated basin of Haycock Brook where the flow per square mile between Mahwah and Pompton Lakes was utilized. Sectional monthly reconstructed flows were calculated for months with sufficient data using equation 4.

$$mReconXXsec = mReconXX - \Sigma_{upstream\_gages}(mRecon_{gage}) \quad (4)$$

where

mReconXXsec is sectional monthly reconstructed flows at site *XX*, in cubic feet per second;

mReconXX is monthly reconstructed flows at site *XX*, in cubic feet per second; and

$mRecon_{gage}$ is monthly reconstructed flows at each selected streamgage upstream from site *XX*, in cubic feet per second.

Sectional monthly reconstructed flows were computed first from available observed flows. For periods without observed flows, sectional monthly reconstructed flows also were estimated as previously described using a MOVE1 regression with index gages. Periods of missing sectional reconstructed flows are given in table 9.

Monthly reconstructed flows at selected sites were determined by (1) calculating and estimating monthly reconstructed flows at the upstream streamgages, (2) calculating and estimating sectional monthly reconstructed flows to the site, and (3) summing the two sets of values. The general equation for these sites is equation 5.

$$mReconXY = \left(\frac{Dxy}{Dxx}\right) \times mReconXXsec + \sum_{upstream\_gages}(mRecon_{gage}) \quad (5)$$

where

mReconXY is monthly reconstructed flows at site *XY*, in cubic feet per second;

Dxy is drainage area of sectional monthly reconstructed flows of site *XY*, in square miles;

Dxx is drainage area of sectional monthly reconstructed flows site *XX*, in square miles;

mReconXXsec is sectional monthly reconstructed flows at site *XX* originating downstream from selected streamgage, in cubic feet per second; and

$mRecon_{gage}$ is monthly reconstructed flows at selected streamgage, in cubic feet per second.

Determination of Daily Reconstructed Flows from Monthly Reconstructed Flows

Daily reconstructed streamflows were determined by disaggregating monthly reconstructed streamflows on the basis of observed streamflow at selected "disaggregation" streamgages (table 10, fig. 3). A primary and a secondary disaggregation streamgage are shown in table 10 for most sites. In the event that the primary disaggregation streamgage did not have sufficient data for the entire study period, the secondary site was used to fill in the remaining period of study. This method was not applied to the five sites at which reconstructed flows were determined from discrete streamflow measurements at partial-record stations.

To disaggregate monthly reconstructed flows, the daily observed streamflow at each disaggregation streamgage was converted from cubic feet per second to percent of total monthly flow for each month of the period of study using equation 6. The total flow is the monthly flow times the days in the month.

$$q\_disagg_{pct} = 100 \times \left(\frac{q\_disagg_{cfs}}{m\_disagg_{cfs} \times days}\right) \quad (6)$$

where

q_disagg_{pct} is daily observed streamflow at disaggregation streamgage, in percent of total monthly streamflow;

q_disagg_{cfs} is daily observed streamflow at disaggregation streamgage, in cubic feet per second;

m_disagg_{cfs} is monthly mean observed streamflow at disaggregation streamgage, in cubic feet per second; and

day s is number of days in the month.

Then, daily reconstructed streamflows at the reconstruction site were estimated from the daily observed streamflows, in percent of total monthly streamflow, at a disaggregation streamgage using equation 7.

$$q\,\mathrm{Re}\,conXX_{cfs} = \frac{mReconXX_{cfs} \times qdisagg_{pct} \times days}{100} \quad (7)$$

where

$q\_ReconXX_{cfs}$ is daily reconstructed flow at reconstruction site XX, in cubic feet per second;

$m\_ReconXX_{cfs}$ is monthly reconstructed flow at reconstruction site XX, in cubic feet per second;

q_disagg_{pct} is daily observed streamflow at disaggregation streamgage, in percent of total monthly streamflow; and

days is number of days in the month.

Table 8. Sources of monthly rates of transfer at selected surface-water pipe diversion sites in northern New Jersey and southeastern New York.

[n.a., not applicable; N.J., New Jersey; N.Y., New York; NJDEP, New Jersey Department of Environmental Protection; NJDWSC, North Jersey District Water Supply Commission; USGS, U.S. Geological Survey]

Diversion index number	Diversion site name (USGS station number)	Source of monthly rates of transfer		Comment (USGS station number)
		As reported in	Source of data or method for estimation	
Sparkill Creek subbasin				
Div01	Sparkill Creek diversion at Northvale, N.J. (01376272)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.
Hackensack River subbasin				
Div02	DeForest Lake diversion at West Nyack, N.Y. (01376699) check	New Jersey Geological and Water Survey (2013)	n.a.	n.a.
Div03	Hackensack River diversion at West Nyack, NY (01376790)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.
Div04	Oradell Reservoir diversion at Haworth, N.J. (01378478)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.
Hirshfeld Brook subbasin				
Div05	Hirshfeld Brook diversion at New Milford, N.J. (01378521)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.
Saddle River subbasin				
Div06	Saddle River diversion at Paramus, N.J. (01390520)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.
Double Kill				
Div07	Double Kill diversion from Lake Wawayanda to Cherry Ridge Brook, N.J.	Richard Grabowski (NJDEP, written commun., 2014) and New Jersey Department of Environmental Protection (1983)	n.a.	n.a.
Pequannock River subbasin				
Div09	Charlotteburg Reservoir diversion at Charlotteburg N.J. (01382370)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.

Table 8. Sources of monthly rates of transfer at selected surface-water pipe diversion sites in northern New Jersey and southeastern New York.—Continued

[n.a., not applicable; N.J., New Jersey; N.Y., New York; NJDEP, New Jersey Department of Environmental Protection; NJDWSC, North Jersey District Water Supply Commission; USGS, U.S. Geological Survey]

Diversion index number	Diversion site name (USGS station number)	Source of monthly rates of transfer		Comment (USGS station number)
		As reported in	Source of data or method for estimation	
Wanaque River subbasin				
Div12	Wanaque Reservoir diversion at Wanaque, N.J. (01386980)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.
Div13	Wanaque Reservoir diversion to Oradell Reservoir, N.J. (n.a.)	n.a.	New Jersey Geological and Water Survey (2013) and Dag Madara (NJDWSC, written commun., 2014-2015)	Methods given in the appendix 3
Pompton River subbasin				
Div15	Ramapo River diversion at Pompton Lakes, N.J. (01387990)	n.a.	New Jersey Geological and Water Survey (2013) and Dag Madara (NJDWSC, written commun., 2014-2015)	Methods given in the appendix 3
Div16	Ramapo River diversion to Oradell Reservoir at Pompton Lakes, N.J. (01387991)	n.a.	New Jersey Geological and Water Survey (2013) and Dag Madara (NJDWSC, written commun., 2014-2015)	Methods given in the appendix 3
Div17	Point View Reservoir diversion to Passaic Valley Water Commission at Wayne, N.J. (01387959)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.
Div18	Pompton River diversion at Pompton Plains, N.J., to Point View Reservoir (01388490)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.
Musconetcong River subbasin				
Div19	Lake Hopatcong diversion to Rockaway River, N.J. (n.a.)	Richard Grabowski (NJDEP, written commun., 2014) and New Jersey Department of Environmental Protection (1983)	n.a.	n.a.
Rockaway River subbasin				
Div20	Boonton Reservoir diversion at Boonton, N.J. (01380800)	New Jersey Geological and Water Survey (2013)	n.a.	n.a.

Table 8. Sources of monthly rates of transfer at selected surface-water pipe diversion sites in northern New Jersey and southeastern New York.—Continued

[n.a., not applicable; N.J., New Jersey; N.Y., New York; NJDEP, New Jersey Department of Environmental Protection; NJDWSC, North Jersey District Water Supply Commission; USGS, U.S. Geological Survey]

Diversion index number	Diversion site name (USGS station number)	Source of monthly rates of transfer		Comment (USGS station number)
		As reported in	Source of data or method for estimation	
Main Stem Passaic River subbasin				
Div21	Passaic River diversion near Summit, N.J. (01379510)	New Jersey Geological and Water Survey (2013) and Richard Grabowski (NJDEP, written commun., 2015)	n.a.	n.a.
Div22	Canoe Brook diversion near Summit, N.J. (01379529)	New Jersey Geological and Water Survey (2013) and Richard Grabowski (NJDEP, written commun., 2015)	n.a.	n.a.
Div23	Pompton River diversion to Wanaque Reservoir at Two Bridges, N.J. (01388980)	n.a.	New Jersey Geological and Water Survey (2013) and Dag Madara (NJDWSC, written commun., 2014–15)	Methods given in the appendix 3
Div24	Pompton River diversion to Oradell Reservoir at Two Bridges, N.J. (01388981)	n.a.	New Jersey Geological and Water Survey (2013) and Dag Madara (NJDWSC, written commun., 2014–15)	Methods given in the appendix 3
Div25	Pompton River diversion to Passaic Valley Water Commission at Two Bridges, N.J. (01388982)	New Jersey Geological and Water Survey (2013)	n.a.	Prior to 2000 water year, diversions included Passaic River diversion at Little Falls, N.J. (01389490).
Div26	Passaic River diversion at Little Falls, N.J. (01389490)	New Jersey Geological and Water Survey (2013)	n.a.	Prior to the 2000 water year, diversions were included as part of Pompton River diversion to Passaic Valley Water Commission at Two Bridges, N.J. (01388982).

Table 9. Periods of calculated reconstructed flows used to develop relations at selected flow-reconstruction sites, by subbasin, in northern New Jersey and southeastern New York and periods over which monthly reconstructed flows were estimated with these relations.

[N.Y., New York; N.J., New Jersey; T, total monthly reconstructed flows; Sec, sectional monthly reconstructed flows]

Type of monthly reconstructed flows determined from MOVE1 relations	Period of calculated monthly reconstructed flows used to determine MOVE1 relations, in water years		Period of estimates of monthly reconstructed flows used to fill in missing calculated values, in water years[1]	
	First	Last	First	Last
(Recon02) Sparkill Creek at Sparkill, N.Y.				
T	1960	1978	1922	2010
(Recon04) Hackensack River at West Nyack, N.Y.				
T	1959	1979	1922	1959
(Recon06) Hackensack River at Rivervale, N.J.				
T	1942	1961	1922	1941
(Recon08) Pascack Brook at Westwood, N.J.				
T	1935	1954	1922	1934
(Recon11) Saddle River at Upper Saddle River, N.J.				
T	1955	1974	1922	1988
T	1964	1986	1975	1977
T	1978	1999	1986	1988
(Recon12) Saddle River at Ridgewood, N.J.				
T	1955	1974	1922	1954
T	1964	1986	1975	1977
T	1978	1999	1986	1988
(Recon14) Saddle River below Hohokus Brook at Paramus, N.J.				
T	1924	1943	1922	1923
(Recon26) Pequannock River at Macopin Intake Dam, N.J.				
T	1923	1942	1922	1922
T	1980	2002	1990	1992
(Recon29) Wanaque River at outlet of Greenwood Lake at Awosting, N.J.				
T	1984	2004	1994	1994
(Recon30) Wanaque River at outlet of Monksville Reservoir at Monks, N.J.				
T	1935	1954	1922	1934
T	1965	1985	1985	2010
(Recon31) Wanaque River at outlet of Wanaque Reservoir at Wanaque, N.J.				
T	1984	2004	1994	1994
(Recon35) Ramapo River at Pompton Lakes, N.J.				
Sec	1923	1942	1922	1923
(Recon37) Pompton River at Pompton Plains, N.J.				
T	1923	1942	1922	1923
T	1981	2003	1990	1994
(Recon38) Musconetcong River at outlet of Lake Hopatcong, N.J.				
T	1961	1975	1922	1960
T	1964	2010	1976	2002
(Recon39) Beaver Brook at outlet of Splitrock Reservoir near Hibernia, N.J.				
T	1976	1988	1922	2010
(Recon41) Rockaway River above Reservoir at Boonton, N.J.				
T	1938	1957	1922	1937
(Recon44) Whippany River near Morristown, N.J.				
T	1995	2010	1922	1995
(Recon48) Canoe Brook at diversion near Summit, N.J.				
T	1966	2000	1922	1990
(Recon49) Passaic River at Pine Brook, N.J.				
T	2006	2010	1922	2005
Sec	2006	2010	1922	2005
(Recon53) Passaic River at Little Falls, N.J.				
T	1985	2004	1994	1994
Sec	2006	2010	1922	2005

[1]Each period of estimates of monthly reconstructed flows may include some calculated monthly reconstructed flows.

Table 10. Disaggregation streamgages used to determine daily reconstructed flows from monthly reconstructed flows at flow-reconstruction sites in northern New Jersey and southeastern New York.

[n.a., not applicable; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Flow-reconstruction site		Disaggregation streamgage (USGS station number)	
Index number	**Name (USGS station number)**	**Primary**	**Secondary**
	Sparkill Creek		
Recon01	Sparkill Creek at diversion at Northvale, N.J. (n.a.)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon02	Sparkill Creek at Sparkill, N.Y. (01376280)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
	Hackensack River		
Recon03	Hackensack River at outlet of DeForest Lake at West Nyack, N.Y. (n.a.)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon04	Hackensack River at West Nyack, N.Y. (01376800)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon05	Hackensack River at outlet of Lake Tappan at Old Tappan, N.J. (n.a.)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon06	Hackensack River at Rivervale, N.J. (01377000)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon07	Pascack Brook at Woodcliff Lake outlet at Hillsdale, N.J. (01377451)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon08	Pascack Brook at Westwood, N.J. (01377500)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon09	Hackensack River at New Milford, N.J. (01378500)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
	Hirshfeld Brook		
Recon10	Hirshfeld Brook at diversion at New Milford, N.J. (n.a.)	n.a.	n.a.
	Saddle River		
Recon11	Saddle River at Upper Saddle River, N.J. (01390450)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon12	Saddle River at Ridgewood, N.J. (01390500)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon13	Saddle River below diversion at Paramus, N.J. (01390530)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
Recon14	Saddle River below Hohokus Brook at Paramus, N.J. (01391102)	Saddle River at Lodi (01391500)	Ramapo River at Pompton Lakes (01388000)
	Double Kill		
Recon15	Double Kill at outlet of Wawayanda Lake at Wawayanda, N.J. (n.a.)	n.a.	n.a.
	Pequannock River		
Recon16	Pequannock River diversion to Canistear Reservoir near Vernon, N.J. (n.a.)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Recon17	Pacock Brook at outlet of Canistear Reservoir near Stockholm, N.J. (n.a.)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Recon18	Peqannock River tributary at outlet of Dunker Pond, N.J. (n.a.)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Recon19	Pequannock River at Oak Ridge, N.J. (01382210)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)

Table 10. Disaggregation streamgages used to determine daily reconstructed flows from monthly reconstructed flows at flow-reconstruction sites in northern New Jersey and southeastern New York.—Continued

[n.a., not applicable; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Flow-reconstruction site		Disaggregation streamgage (USGS station number)	
Index number	Name (USGS station number)	Primary	Secondary
Pequannock River—Continued			
Recon20	Tributary to Clinton Reservoir at outlet of Hanks Pond, N.J. (n.a.)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Recon21	Tributary to Clinton Reservoir at outlet of Cedar Pond, N.J. (n.a.)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Recon22	Clinton Brook at outlet of Clinton Reservoir near Newfoundland, N.J. (n.a.)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Recon23	Pequannock River at Charlotteburg, N.J. (01382381)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Recon24	Mathews Brook diversion near Macopin, N.J. (01382430)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Recon25	Macopin River at Echo Lake, N.J. (01382410)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Recon26	Pequannock River at Macopin Intake Dam, N.J. (01382500)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Ramapo River at Pompton Lakes, N.J. (01388000)
Long House Creek			
Recon27	Auxiliary out of Upper Greenwood Lake at Moe, N.J. (01368720)	n.a.	n.a.
Recon28	Long House Creek at outlet of Upper Greenwood Lake, N.J. (01368721)	n.a.	n.a.
Wanaque River			
Recon29	Wanaque River at outlet of Greenwood Lake at Awosting, N.J. (01383500)	Wanaque River at Awosting (01383500)	Wanaque River at Monks, N.J. (01384000)
Recon30	Wanaque River at outlet of Monksville Reservoir at Monks, N.J. (01384000)	Wanaque River at Monks, N.J. (01384000)	Wanaque River at Awosting, N.J. (01383500)
Recon31	Wanaque River at outlet of Wanaque Reservoir at Wanaque, N.J. (01387000)	Wanaque River at Monks, N.J. (01384000)	Wanaque River at Awosting, N.J. (01383500)
Pompton River			
Recon32	Stone House Brook at outlet of Butler Reservoir (n.a.)	n.a.	n.a.
Recon33	Posts Brook above Wanaque diversion near Wanaque, N.J. (01387019)	n.a.	n.a.
Recon34	Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (01387020)	n.a.	n.a.
Recon35	Ramapo River at Pompton Lakes, N.J. (01388000)	Ramapo River at Pompton Lakes, N.J. (01388000)	n.a.
Recon36	Haycock Brook at outlet of Point View Reservoir near Pompton Plains, N.J. (n.a.)	Ramapo River at Pompton Lakes, N.J. (01388000)	n.a.
Recon37	Pompton River at Pompton Plains, N.J. (01388500)	Ramapo River at Pompton Lakes, N.J. (01388000)	n.a.
Musconetcong River			
Recon38	Musconetcong River at outlet of Lake Hopatcong, N.J. (01455500)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Whippany River at Morristown, N.J. (01381500)

Table 10. Disaggregation streamgages used to determine daily reconstructed flows from monthly reconstructed flows at flow-reconstruction sites in northern New Jersey and southeastern New York.—Continued

[n.a., not applicable; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Flow-reconstruction site		Disaggregation streamgage (USGS station number)	
Index number	**Name (USGS station number)**	**Primary**	**Secondary**
	Rockaway River		
Recon39	Beaver Brook at outlet of Splitrock Reservoir near Hibernia, N.J. (01380000)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Whippany River at Morristown, N.J. (01381500)
Recon40	Stoney Brook tributary at outlet of Taylortown Reservoir, N.J. (n.a.)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Whippany River at Morristown, N.J. (01381500)
Recon41		Rockaway River above Reservoir at Boonton, N.J. (01380500)	Whippany River at Morristown, N.J. (01381500)
Recon42	Rockaway River below Reservoir at Boonton, N.J. (01381000)	Rockaway River above Reservoir at Boonton, N.J. (01380500)	Whippany River at Morristown, N.J. (01381500)
	Whippany River		
Recon43	Harmony Brook at outlet of Clyde Potts Reservoir near Brookside, N.J. (n.a.)	Whippany River at Morristown (01381500)	n.a.
Recon44	Whippany River near Morristown, N.J. (01381400)	Whippany River at Morristown (01381500)	n.a.
Recon45	Whippany River at Morristown, N.J. (01381500)	Whippany River at Morristown (01381500)	n.a.
	Main Stem Passaic River		
Recon46	Passaic River near Chatham, N.J. (01379500)	Passaic River near Chatham, N.J. (01379500)	Passaic River near Millington, N.J. (01379000)
Recon47	Passaic River at diversion near Summit, N.J. (n.a.)	Passaic River near Chatham, N.J. (01379500)	Passaic River near Millington, N.J. (01379000)
Recon48	Canoe Brook at diversion near Summit, N.J. (01379530)	Whippany River at Morristown, N.J. (01381500)	n.a.
Recon49	Passaic River at Pine Brook, N.J. (01381900)	Passaic River at Little Falls, N.J. (01389500)	n.a.
Recon50	Passaic River at Two Bridges, N.J. (01382000)	Passaic River at Little Falls, N.J. (01389500)	n.a.
Recon51	Pompton River at Two Bridges, N.J. (01389000)	Passaic River at Little Falls, N.J. (01389500)	n.a.
Recon52	Passaic River above Beatties Dam at Little Falls, N.J. (01389492)	Passaic River at Little Falls, N.J. (01389500)	n.a.
Recon53	Passaic River at Little Falls, N.J. (01389500)	Passaic River at Little Falls, N.J. (01389500)	n.a.

Application of Methods to Flow-Reconstruction Sites in Each Subbasin

Data types and streamflow adjustment terms used for each flow-reconstruction site are presented in detail for each subbasin. Data types include partial-record streamflow, observed streamflow, or streamflow data determined by drainage area adjustment from nearby sites. Adjustment terms include surface-water diversions and changes in reservoir storage for each site. Subbasins are discussed in groups.

Hackensack River, Saddle River, Hirshfeld Brook, and Sparkill Creek

Features of these subbasins are shown in figure 4 (map) and figure 10 (schematic diagram of streamflow). Data types used to reconstruct flows at each flow-reconstruction site are presented in table 11. The components of streamflow adjustments are shown in table 12.

Reconstructed streamflows at sites in the Hackensack River subbasin were determined from monthly streamflows (tables 11 and 12, fig. 10). Reconstructed flows at the following sites were determined from adjustments of observed streamflows: Hackensack River at West Nyack, N.Y. (Recon04); Hackensack River at Rivervale, N.J. (Recon06); Hackensack River at New Milford, N.J. (Recon09); and Pascack Brook at Westwood, N.J. (Recon08). Streamflow adjustments (diversions and changes in reservoir storage) are presented in table 12. Missing values of change in storage for Woodcliff Lake during water years 1922–30 were set to zero for calculations for Hackensack River at New Milford, N.J. (Recon09). Reconstructed flows at three other sites—Hackensack River at outlet of DeForest Lake at West Nyack, N.Y. (Recon03); Hackensack River at outlet of Lake Tappan at Old Tappan, N.J. (Recon05); and Pascack Brook at Woodcliff Lake outlet at Hillsdale, N.J. (Recon07) —were determined from drainage-area adjustment of flows at one of the previous four sites, as indicated in table 11.

Reconstructed flows at the sites in the Saddle River subbasin were all determined from monthly data (tables 11 and 12, fig. 10). Reconstructed flows at three sites—Saddle River at Upper Saddle River, N.J. (Recon11); Saddle River at Ridgewood, N.J. (Recon12); and Saddle River below Hohokus Brook at Paramus, N.J. (Recon14)—were determined from adjustments of observed flows. Reconstructed flows at the site on the Saddle River below diversion at Paramus, N.J. (Recon13), were determined from drainage-area adjustment of corresponding flows at the site on the Saddle River at Ridgewood, N.J. (Recon12).

Reconstructed flows at the site in the Hirshfeld Brook subbasin (Recon10) were determined from estimated daily observed flows at the partial-record station on Hirshfeld Brook at New Milford, N.J. (01378520), after adjustment for drainage area (table 11, fig. 10). The flow-reconstruction site at the diversion is downstream from this partial-record station.

Reconstructed flows at the two sites in the Sparkill Creek subbasin were determined from monthly data (tables 11 and 12, fig. 10). Reconstructed flows at the streamgage at Sparkill, N.J. (Recon02), were determined from adjustment of observed flows. Reconstructed flows at Sparkill Creek at diversion at Northvale, N.J. (Recon01), were determined from drainage-area adjustment of reconstructed flows at the site at the streamgage (Recon02).

Pequannock River and Double Kill

Reconstruction sites in the subbasins of the Pequannock River and Double Kill are shown in figures 5 (map) and 11 (schematic diagram of streamflow). Data types for each reconstruction site in the subbasins of the Pequannock River and Double Kill are given in table 13. Components of streamflow adjustment terms are presented in table 14.

Reconstructed flows at all 11 sites in the Pequannock River subbasin were determined from monthly data (tables 13 and 14, fig. 11). In addition, reconstructed flows at the site on the Pequannock River at Macopin Intake Dam, N.J. (Recon26), were determined by adjustment of observed streamflow measured at this site for changes in storage in five reservoirs and for two diversions. Reconstructed flows at the other 10 sites were determined from drainage-area adjustment of the reconstructed flows at Pequannock River at Macopin Intake Dam, N.J. (Recon26).

Reconstructed flows at the one site in the Double Kill subbasin (Recon15) were determined from drainage-area adjustment of the monthly observed flows at the partial-record station on Double Kill at Wawayanda, N.J. (01368820), (tables 6 and 13, fig. 11). The monthly observed flows at this partial-record station were estimated from discrete streamflow measurements.

Wanaque River and Long House Creek

Flow-reconstruction sites in the Wanaque River and Long House Creek subbasins are shown in figures 6 (map) and 12 (streamflow schematic diagram). Flow-reconstruction data types are presented in table 15. Streamflow adjustment terms are given in table 16.

Reconstructed flows at the three sites in the Wanaque River subbasin were determined from the adjustment of monthly observed streamflows at each site (tables 15 and 16, fig. 12): Wanaque River at outlet of Greenwood Lake at Awosting, N.J. (Recon29); Wanaque River at outlet of Monksville Reservoir at Monks, N.J. (Recon30); and Wanaque River at outlet of Wanaque Reservoir at Wanaque, N.J. (Recon31). Streamflow was adjusted for diversions and for changes in storage in three reservoirs (table 16). Streamflows measured at the Wanaque River at outlet of Monksville Reservoir at Monks, N.J. (Recon30), were not adjusted for storage in the Monksville Reservoir because the streamgage at this site (01384000) was operated prior to the construction of the reservoir.

Daily reconstructed flows at the two sites in the Long House Creek subbasin were determined from discrete streamflow measurements at two partial-record stations (table 15, fig. 12). The reconstructed flows at the Auxiliary out of Upper Greenwood Lake at Moe, N.J. (Recon27), were estimated from records from the partial-record station at this site (01368720). The reconstructed flows at the Long House Creek at outlet of Upper Greenwood Lake, N.J. (Recon28), were determined from drainage-area adjustment of daily reconstructed flows determined at the downstream partial-record station on Long House Creek below Cascade Lake, N.Y. (01368722), from discrete streamflow measurements at this station.

Pompton River

Flow-reconstruction sites in the subbasin of the Pompton River are shown in figures 7 (map) and 13 (streamflow schematic diagram). Data types used in streamflow reconstruction are presented in table 17. Streamflow adjustment terms for calculation of monthly reconstructed flows are shown in table 18. Streamflow adjustment terms for the upstream streamgage used for calculation of sectional monthly reconstructed flows at one site in the Pompton River subbasin are listed in table 19.

Reconstructed flows at the two sites on Posts Brook were determined from analysis of discrete measurements of streamflow at two partial-record stations (table 17, fig. 13). Reconstructed daily flows at Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (Recon34), were determined from estimated daily observed streamflows at the partial-record station at this site (01387020). Reconstructed daily flows at Posts Brook above Wanaque diversion near Wanaque, N.J. (Recon33), are the sums of estimated daily observed flows of the Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (Recon34), and the partial-record station on Posts Brook below diversion to Wanaque Reservoir near Wanaque, N.J. (01387021).

Reconstructed flows at Stone House Brook at outlet of Butler Reservoir, N.J. (Recon32), (table 17, fig. 13) were determined from drainage-area adjustment of monthly reconstructed flows for Beaver Brook at outlet of Splitrock Reservoir, N.J. (Recon39), in the Rockaway River subbasin (table 17, fig. 13). The reconstruction of flows at the site on Beaver Brook is discussed below in section "Rockaway River, Musconetcong River, and Whippany River."

Reconstructed flows at Ramapo River at Pompton Lakes, N.J. (Recon35), and Pompton River at Pompton Plains, N.J. (Recon37), were determined by adjusting monthly measured streamflows at each site (table 17, fig. 13); adjustment terms are shown in table 18. Streamflows at the site on the Ramapo River (Recon35) were adjusted for the diversions on the Ramapo River at Pompton Lakes (Div15 and Div16). Streamflows at the site on the Pompton River (Recon37) were adjusted for diversions in the subbasins of the Pompton River and for diversions and changes in reservoir storage upstream from the Pequannock River at Macopin Intake Dam, N.J. (Recon26), and Wanaque River at Wanaque, N.J. (Recon31).

Reconstructed flows at Haycock Brook at outlet of Point View Reservoir near Pompton Plains, N.J. (Recon36), were determined from drainage-area adjustment of sectional monthly reconstructed flows between Ramapo River at Pompton Lakes, N.J., and Ramapo River near Mahwah, N.J., (Recon35sec) (table 17). Adjustment terms for the determination of sectional monthly reconstructed flows for the Ramapo River at Pompton Lakes, N.J. (Recon35sec), are presented in table 19.

Rockaway River, Musconetcong River, and Whippany River

Flow-reconstruction sites in the subbasins of the Rockaway, Musconetcong, and Whippany Rivers are shown in figures 8 (map) and 14 (streamflow schematic diagram). Data types used in flow reconstruction are presented in table 20; streamflow adjustment terms are shown in table 21.

Reconstructed flows at all sites in the subbasins of the Rockaway, Musconetcong, and Whippany Rivers were determined from monthly data (table 20, fig. 14). Reconstructed flows at six sites were determined by adjusting observed streamflows at each site: Musconetcong River at outlet of Lake Hopatcong, N.J. (Recon38); Beaver Brook at outlet of Splitrock Reservoir near Hibernia, N.J. (Recon39); Rockaway Rive above Reservoir at Boonton, N.J. (Recon41); Rockaway River below Reservoir at Boonton, N.J. (Recon42); Whippany River near Morristown, N.J. (Recon44); and Whippany River at Morristown, N.J. (Recon45). Streamflow adjustment terms are presented in table 21.

Monthly flow adjustment and monthly reconstructed flows at Rockaway River above Reservoir at Boonton, N.J. (Recon41), and Rockaway River below Reservoir at Boonton, N.J. (Recon42), were calculated with some missing values of changes in storage in Splitrock Reservoir set to zero. This period of record is water years 1922–49 (table 3).

Reconstructed flows at one site in the Rockaway River subbasin and one site in the Whippany River subbasin were determined from drainage-area adjustment of monthly reconstructed flows at other sites (fig. 14, table 20). Reconstructed streamflows at Stony Brook tributary at outlet of Taylortown Reservoir, N.J. (Recon40), were determined by drainage area adjustment of reconstructed flows in Beaver Brook at outlet of Splitrock Reservoir near Hibernia, N.J. (Recon39). Reconstructed flows at Harmony Brook at outlet of Clyde Potts Reservoir near Brookside, N.J. (Recon43), were determined from reconstructed flows for the Whippany River near Morristown, N.J. (Recon44).

Main Stem Passaic River

Flow-reconstruction sites in the Main Stem Passaic River subbasin are shown in figures 9 (map) and 15 (streamflow schematic diagram). Data types used for reconstruction at each site are presented in table 22; streamflow adjustment terms are shown in table 23.

Reconstructed flows at all sites in the subbasin of the Main Stem Passaic River were determined from monthly data (tables 22 and 23, fig. 15). Reconstructed flows at the following four sites in the subbasin of the Main Stem Passaic River were determined from adjustment of monthly observed streamflow: Passaic River near Chatham, N.J. (Recon46); Canoe Brook near Summit, N.J. (Recon48); Passaic River at Pine Brook, N.J. (Recon49); and Passaic River at Little Falls, N.J. (Recon53).

Reconstructed flows at Passaic River at Little Falls, N.J. (Recon53), were calculated with some missing diversions set to zero (table 23). The diversions are Passaic River diversion near Summit, N.J. (Div21), and Canoe Brook diversion near Summit, N.J. (Div22). The periods of missing values set to zero are water years 1922–65 and 1975–78 (table 4).

Reconstructed flows at two sites in the Main Stem Passaic River subbasin were determined from drainage-area adjustment of flows at other sites (table 22, fig. 15). Flows at the Passaic River at diversion near Summit, N.J. (Recon47), were determined from those at the Passaic River near Chatham, N.J. (Recon46). Flows at the Passaic River above Beatties Dam at Little Falls, N.J. (Recon52), were determined from those at the Passaic River at Little Falls, N.J. (Recon53). Reconstructed flows at Passaic River at Pine Brook, N.J. (Recon49), were determined by summing sectional monthly reconstructed flows (table 22) and reconstructed flows at upstream sites (tables 22 and 19).

Reconstructed flows at the Passaic River at Two Bridges, N.J. (Recon50), were determined by summing sectional reconstructed flows for the site with monthly reconstructed flows at Passaic River at Pine Brook, N.J. (Recon49) (table 22). Sectional monthly reconstructed flows at the Passaic River at Two Bridges, N.J. (Recon50), were estimated from drainage-area adjustment of sectional monthly reconstructed flows at Passaic River at Little Falls, N.J. (table 19).

Reconstructed flows at the Pompton River at Two Bridges, N.J. (Recon51), were determined by summing sectional reconstructed flows for the site with monthly reconstructed flows at Pompton River at Pompton Plains, N.J. (Recon37) (table 22). Sectional monthly reconstructed flows at Pompton River at Two Bridges, N.J. (Recon51), were estimated from drainage-area adjustment of sectional monthly reconstructed flows at Passaic River at Little Falls, N.J. (Recon53sec) (table 19).

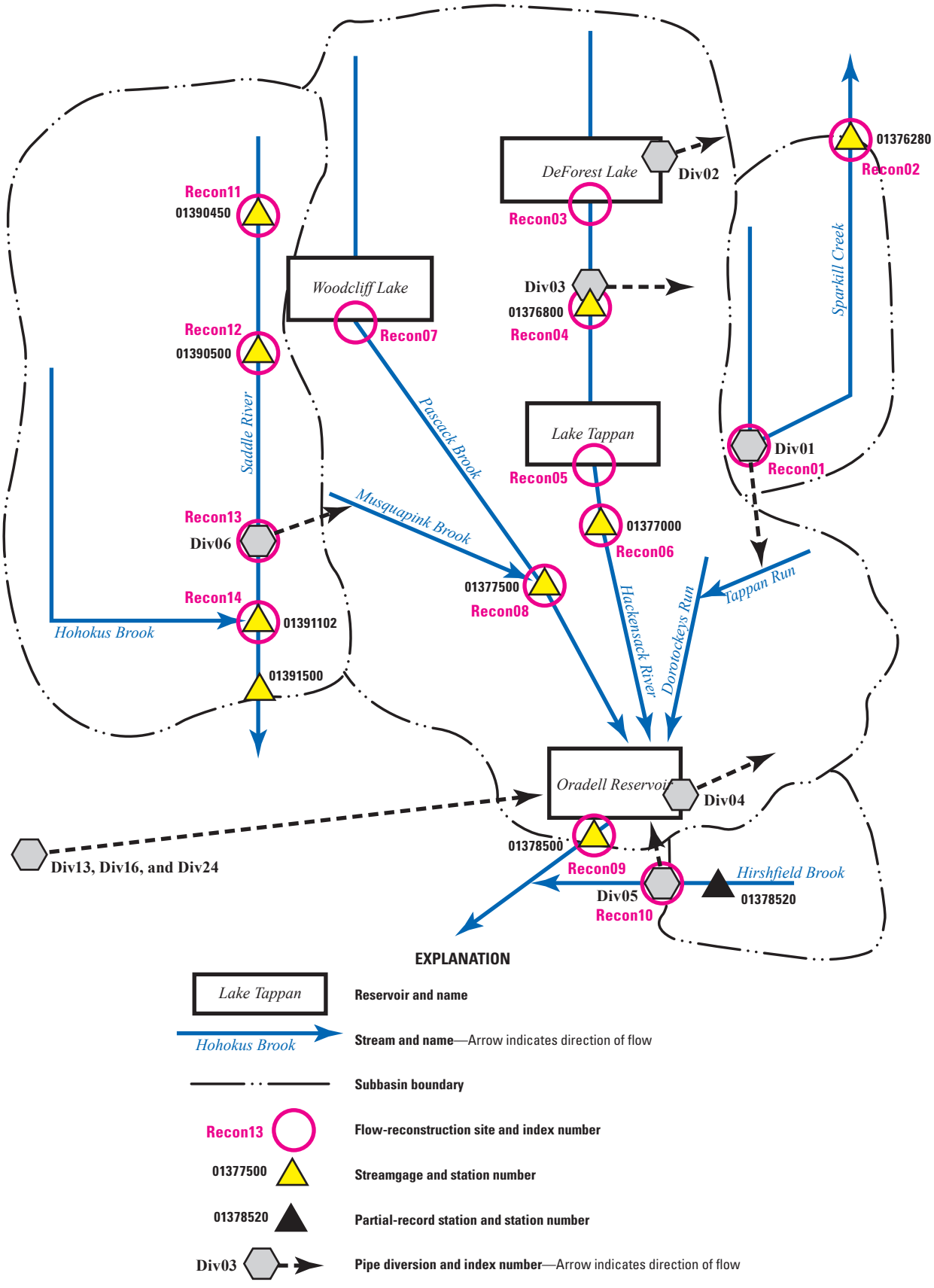

Figure 10. Streamflow in the subbasins of the Hackensack River, Saddle River, Hirshfeld Brook, and Sparkill Creek, northern New Jersey and southeastern New York.

Table 11. Data types used to determine reconstructed flows at sites in the subbasins of Hackensack River, Saddle River, Hirshfeld Brook, and Sparkill Creek, northern New Jersey and southeastern New York, during 1922–2010.

[Periods of discrete streamflow measurements and calculated monthly reconstructed flows are not necessarily complete; n.a., not applicable; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Flow-reconstruction site		Data types used to determine reconstructed streamflows at flow-reconstruction site, by subbasin				
		Daily observed streamflows estimated from discrete streamflow measurements at indicated partial-record station(s)		Monthly values of observed streamflow at site		Drainage-area adjustment of monthly reconstructed flows at a different flow-reconstruction site (flow-reconstruction site index number)
Index number	Name	Partial-record station (USGS station number)	Period of discrete streamflow measurements, in water years	USGS station number of streamgage at site	Period of calculated monthly reconstructed flows, in water years	
			Hackensack River			
Recon03	Hackensack River at outlet of DeForest Lake at West Nyack, N.Y.	n.a.	n.a.	n.a.	n.a.	Hackensack River at West Nyack, N.Y (Recon04)
Recon04	Hackensack River at West Nyack, N.Y.	n.a.	n.a.	01376800	1958–2010	n.a.
Recon05	Hackensack River at outlet of Lake Tappan at Old Tappan, N.J.	n.a.	n.a.	n.a.	n.a.	Hackensack River at Rivervale, N.J. (Recon06)
Recon06	Hackensack River at Rivervale, N.J.	n.a.	n.a.	01377000	1942–2010	n.a.
Recon07	Pascack Brook at Woodcliff Lake outlet at Hillsdale, N.J.	n.a.	n.a.	n.a.	n.a.	Pascack Brook at Westwood, N.J. (Recon08)
Recno08	Pascack Brook at Westwood, N.J.	n.a.	n.a.	01377500	1935–2010	n.a.
Recon09	Hackensack River at New Milford, N.J.	n.a.	n.a.	01378500	1922–2010	n.a.
			Saddle River			
Recon11	Saddle River at Upper Saddle River, N.J.	n.a.	n.a.	[1]01390450	1955–2010	n.a.
Recon12	Saddle River at Ridgewood, N.J.	n.a.	n.a.	01390500	1955–2010	n.a.
Recon13	Saddle River below diversion at Paramus, N.J.	n.a.	n.a.	n.a.	n.a.	Saddle River at Ridgewood, N.J. (Recon12)
Recon14	Saddle River below Hohokus Brook at Paramus, N.J.	n.a.	n.a.	[1]01391102	1924–2010	n.a.
			Hirshfeld Brook			
Recon10	Hirshfeld Brook at diversion at New Milford, N.J.	Hirshfeld Brook at New Milford, N.J. (01378520)	1965–2010	n.a.	n.a.	n.a.
			Sparkill Creek			
Recon01	Sparkill Creek at diversion at Northvale, N.J.	n.a.	n.a.	n.a.	n.a.	Sparkill Creek at Sparkill, N.Y. (Recon02)
Recon02	Sparkill Creek at Sparkill, N.Y.	n.a.	n.a.	01376280	1960–1978	n.a.

[1]Monthly observed streamflows were estimated from records of corresponding streamflow of one or more nearby gages.

Table 12. Streamflow adjustment terms used to calculate monthly reconstructed flows at selected flow-reconstruction sites in the subbasins of Sparkill Creek, Hackensack River, and Saddle River, northern New Jersey and southeastern New York, during water years 1922–2010.

[n.a., not applicable; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Index number	Name (USGS station number of streamgage at site)	Components of streamflow adjustment terms			Reconstruction equations[1]
		Selected diversions moving water into drainage area of flow-reconstruction site (diversion index)	Selected diversions moving water out of drainage area of flow-reconstruction site (diversion index)	Change in monthly storage in identified reservoirs	
Hackensack River					
Recon04	Hackensack River at West Nyack, N.Y. (01376800)	n.a.	(Div02) DeForest Lake diversion at West Nyack, N.Y. (Div03) Hackensack River diversion at West Nyack, N.Y	Lake DeForest	mRecon04 = m01376800 + DeForest + Div02 + Div03
Recon06	Hackensack River at Rivervale, N.J. (01377000)	n.a.	(Div02) DeForest Lake diversion at West Nyack, N.Y. (Div03) Hackensack River diversion at West Nyack, N.Y	Lake DeForest Lake Tappan	mRecon06= m01377000 + DeForest + Tappan + Div02 + Div03
Recon08	Pascack Brook at Westwood, N.J. (01377500)	(Div06) Saddle River diversion at Paramus, N.J.	n.a.	Woodcliff Lake	mRecon08= m01377500 + Woodcliff - Div06
Recon09	Hackensack River at New Milford, N.J. (01378500)	(Div05) Hirshfeld Brook diversion at New Milford, N.J. (Div06) Saddle River diversion at Paramus, N.J. (Div13) Wanaque Reservoir diversion to Oradell Reservoir, N.J. (Div16) Ramapo River diversion to Oradell Reservoir at Pompton Lakes, N.J. (Div24) Pompton River diversion to Oradell Reservoir at Two Bridges, N.J.	(Div02) DeForest Lake diversion at West Nyack, N.Y. (Div03) Hackensack River diversion at West Nyack, N.Y. (Div04) Oradell Reservoir diversion at Haworth, N.J.	Lake DeForest Lake Tappan Woodcliff Lake Oradell Reservoir	mRecon09 = m01378500 + (Div02 + Div03 + Div04 - (Div05 + Div06 + Div13 + Div16 + Div24)) + (DeForest + Tappan + Woodcliff + Oradell)
Saddle River					
Recon11	[2]Saddle River at Upper Saddle River, N.J. (01390450)	n.a.	n.a.	n.a.	mRecon11 = m01390450
Recon12	Saddle River at Ridgewood, N.J. (01390500)	n.a.	n.a.	n.a.	mRecon12 = m01390500
Recon14	[2]Saddle River below Hohokus Brook at Paramus, N.J. (01391102)	n.a.	(Div06) Saddle River diversion at Paramus, N.J.	n.a.	mRecon14 = m01391102 + Div06
Sparkill Creek					
Recon02	Sparkill Creek at Sparkill, N.Y. (01376280)	n.a.	(Div01) Sparkill Creek diversion at Northvale, N.J.	n.a.	mRecon02= m01376280 + Div01

[1] "m" denotes monthly flow.

[2]Monthly observed streamflows were estimated from records of corresponding streamflow of one or more nearby gages.

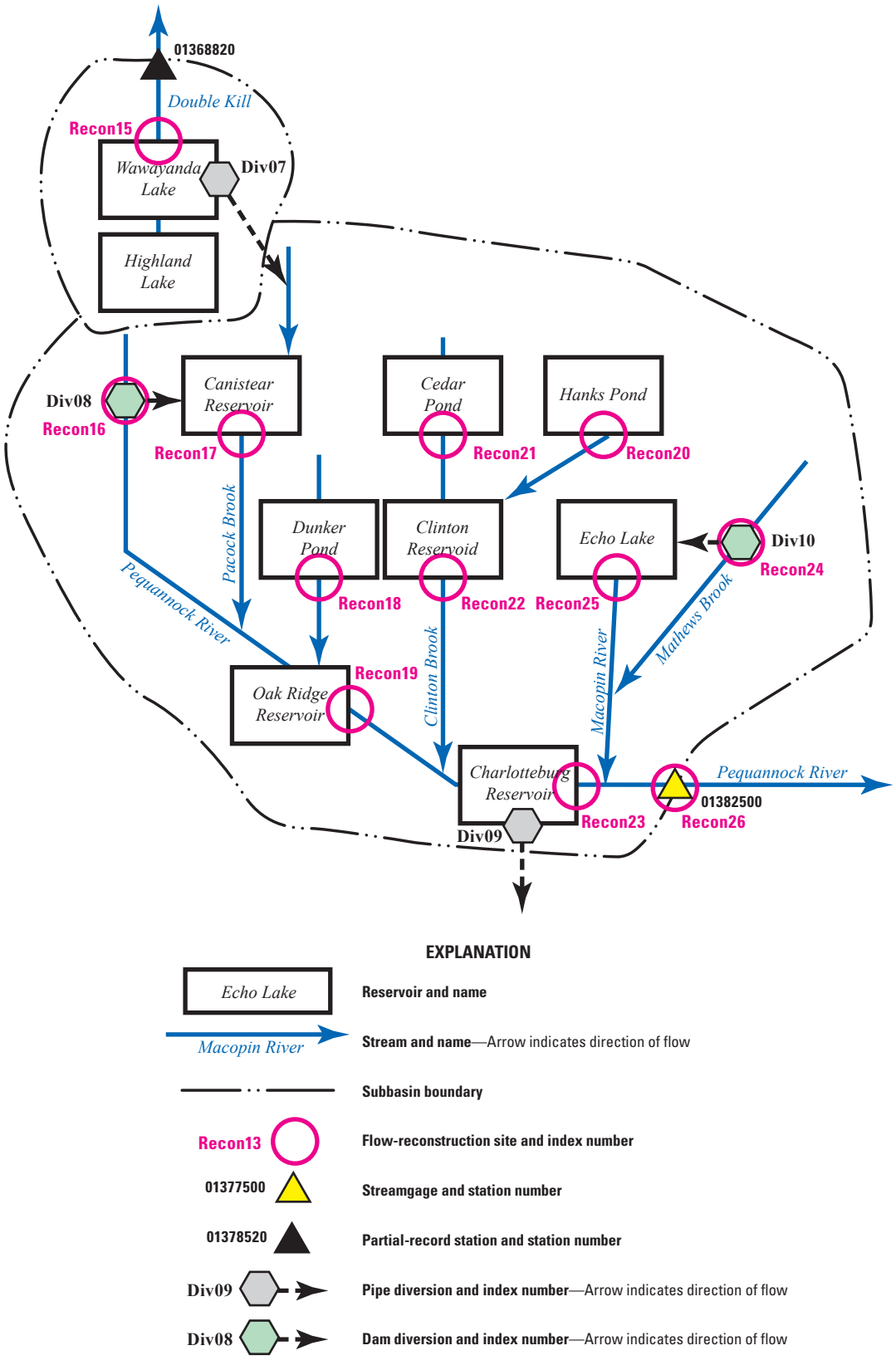

Figure 11. Streamflow in the subbasins of the Pequannock River and Double Kill, northern New Jersey.

Table 13. Data types used to determine reconstructed flows at sites in the subbasins of Pequannock River and Double Kill, northern New Jersey, during water years 1922–2010.

[Periods of discrete streamflow measurements and calculated monthly reconstructed flows are not necessarily complete; n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Index number	Name	Data types used to determine reconstructed streamflows at flow-reconstruction site, by subbasin				
		Daily observed streamflows estimated from discrete streamflow measurements at indicated partial-record station(s)		Monthly values of observed streamflow at site		Drainage-area adjustment of monthly reconstructed flows at a different flow-reconstruction site (flow-reconstruction site index number)
		Partial-record station (USGS station number)	Period of discrete streamflow measurements, in water years	USGS station number of streamgage at site	Period of calculated monthly reconstructed flows, in water years	
			Pequannock River			
Recon16	Pequannock River diversion to Canistear Reservoir near Vernon, N.J. (diversion)	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon17	Pacock Brook at outlet of Canistear Reservoir near Stockholm, N.J.	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon18	Peqannock River tributary at outlet of Dunker Pond, N.J.	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon19	Pequannock River at Oak Ridge, N.J.	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon20	Tributary to Clinton Reservoir at outlet of Hanks Pond, N.J.	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon21	Tributary to Clinton Reservoir at outlet of Cedar Pond, N.J.	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon22	Clinton Brook at outlet of Clinton Reservoir near Newfoundland, N.J.	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon23	Pequannock River at Charlotteburg, N.J.	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon24	Mathews Brook diversion near Macopin, N.J. (diversion)	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon25	Macopin River at Echo Lake, N.J.	n.a.	n.a.	n.a.	n.a.	Pequannock River at Macopin Intake Dam, N.J. (Recon26)
Recon26	Pequannock River at Macopin Intake Dam, N.J.	n.a.	n.a.	01382500	1923–2010	n.a.
			Double Kill			
Recon15	Double Kill at outlet of Wawayanda Lake at Wawayanda, N.J.	Double Kill at Wawayanda, N.J. (01368820)	1998–2012	n.a.	n.a.	n.a.

Table 14. Streamflow adjustment terms used to calculate monthly reconstructed flows at selected flow-reconstruction site in the subbasin of the Pequannock River, northern New Jersey, during water years 1922–2010.

[N.J., New Jersey; USGS, U.S. Geological Survey]

Index number	Name (USGS station number of streamgage at site)	Components of streamflow adjustment terms			Reconstruction equation[1]
		Selected diversion moving water into drainage area of flow-reconstruction site (diversion index)	Selected diversion moving water out of drainage area of flow-reconstruction site (diversion index)	Change in monthly storage in identified reservoir	
Recon26	Pequannock River at Macopin Intake Dam, N.J. (01382500)	(Div07) Double Kill diversion from Lake Wawayanda to Cherry Ridge Brook, N.J.	(Div09) Charlotteburg Reservoir diversion at Charlotteburg, N.J.	Canistear Reservoir Oak Ridge Reservoir Clinton Reservoir Charlotteburg Reservoir Echo Lake	mRecon26 = m01382500 + (Div09 - Div07) + (Canistear + OakRidge + Clinton + Echo + Charlotteburg)

[1] "m" denotes monthly flow.

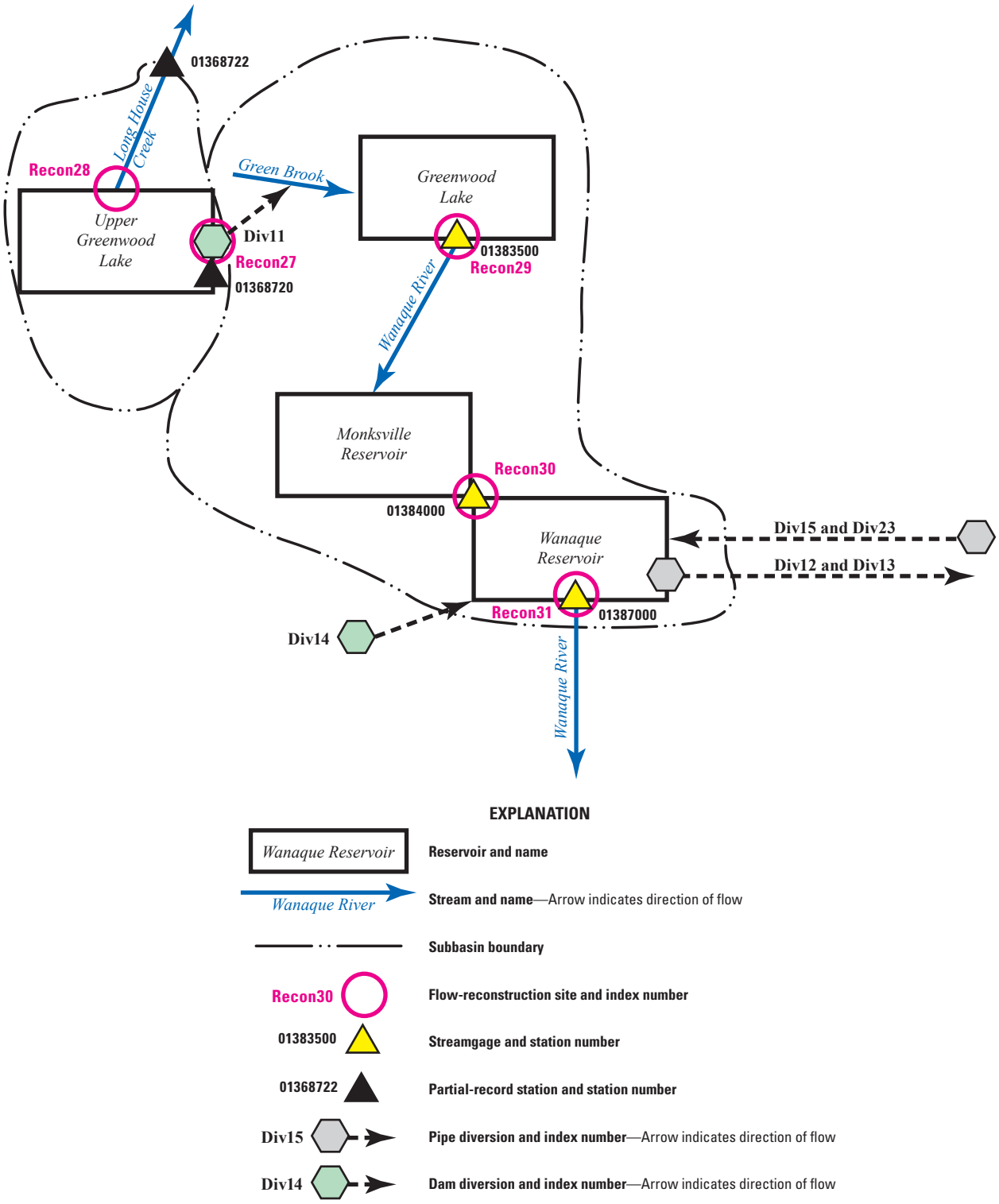

Figure 12. Streamflow in the subbasins of the Wanaque River and Long House Creek, northern New Jersey and southeastern New York.

Table 15. Data types used to determine reconstructed flows at sites in the subbasins of Wanaque River and Long House Creek, northern New Jersey, during water years 1922–2010.

[Periods of discrete streamflow measurements and calculated monthly reconstructed flows are not necessarily complete; n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Index number	Name	Data types used to determine reconstructed streamflows at flow-reconstruction site, by subbasin				
		Daily observed streamflows estimated from discrete streamflow measurements at indicated partial-record station(s)		Monthly values of observed streamflow at site		Drainage-area adjustment of monthly reconstructed flows at a different flow-reconstruction site (flow-reconstruction site index number)
		Partial-record station (USGS station number)	Period of discrete streamflow measurements, in water years	USGS station number of streamgage at site	Period of calculated monthly reconstructed flows, in water years	
			Wanaque River			
Recon29	Wanaque River at outlet of Greenwood Lake at Awosting, N.J.	n.a.	n.a.	01383500	1922–2010	n.a.
Recon30	Wanaque River at outlet of Monksville Reservoir at Monks, N.J.	n.a.	n.a.	01384000	1935–1985	n.a.
Recon31	Wanaque River at outlet of Wanaque Reservoir at Wanaque, N.J.	n.a.	n.a.	01387000	1922–2010	n.a.
			Long House Creek			
Recon27	Auxiliary outlet of Upper Greenwood Lake at Moe, N.J.(diversion)	Auxiliary outlet of [1] Upper Greenwood Lake at Moe, N.J. (01368720)	1975–1980	n.a.	n.a.	n.a.
Recon28	Long House Creek at outlet of Upper Greenwood Lake, N.J.	Long House Creek below Cascade Lake, N.Y. (01368722)	1973–1976	n.a.	n.a.	n.a.

[1] Partial-record station is located at flow-reconstruction site. Drainage-area adjustment was not needed.

Table 16. Streamflow adjustment terms used to calculate monthly reconstructed flows at flow-reconstruction sites in the subbasin of the Wanaque River, northern New Jersey, during water years 1922–2010.

[n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Index number	Name (USGS station number of streamgage at site)	Period of calculated monthly reconstructed flows, in water years (may be incomplete)	Components of streamflow adjustment terms			Reconstruction equation[1]
			Selected diversions moving water into drainage area of flow-reconstruction site (diversion index)	Selected diversions moving water out of drainage area of flow-reconstruction site (diversion index)	Change in monthly storage in identified reservoir	
Recon29	Wanaque River at outlet of Greenwood Lake at Awosting, N.J. (01383500)	1922–2010	(Div11) Auxilary outlet of Upper Greenwood Lake at Moe, N.J.	n.a.	Greenwood Lake	mRecon29 = m01383500 + Greenwood – Div11
Recon30	Wanaque River at outlet of[2] Monksville Reservoir at Monks, N.J. (01384000)	1935–1985	(Div11) Auxiliary outlet of Upper Greenwood Lake at Moe, N.J.	n.a.	Greenwood Lake	mRecon30 = m01384000 + Greenwood – Div11
Recon31	Wanaque River at outlet of Wanaque Reservoir at Wanaque, N.J. (01387000)	1922–2010	(Div11) Auxiliary outlet of Upper Greenwood Lake at Moe, N.J. (Div14) Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (Div15) Ramapo River diversion at Pompton Lakes, N.J. (Div23) Pompton River diversion to Wanaque Reservoir at Two Bridges, N.J.	(Div12) Wanaque Reservoir diversion at Wanaque, N.J. (Div13) Wanaque Reservoir diversion to Oradell Reservoir, N.J.	Greenwood Lake Monksville Reservoir Wanaque Reservoir	mRecon31 = m01387000 + Greenwood + Monksville + Wanaque + (– Div11 - Div14 – Div15 - Div23 + Div12 + Div13)

[1] "m" denotes monthly flow.

[2]This streamgage was operated prior to the construction of the Monksville Reservoir.

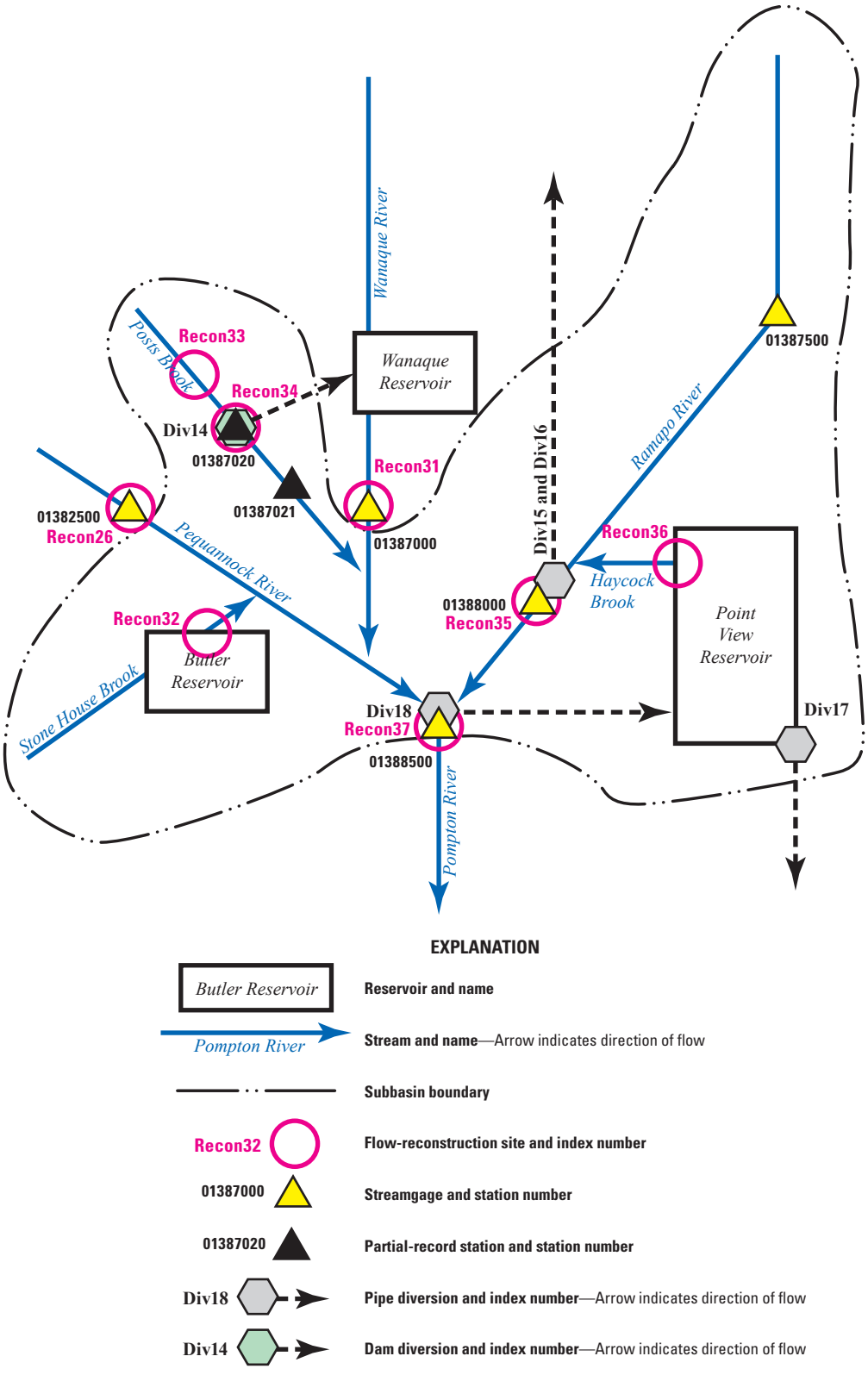

Figure 13. Streamflow in the Pompton River subbasin, northern New Jersey.

Table 17. Data types used to determine reconstructed flows at reconstruction sites in the Pompton River subbasin in northern New Jersey, during water years 1922–2010.

[More information about sectional monthly reconstructed flows is given in table 19; periods of discrete streamflow measurements and calculated monthly reconstructed flows are not necessarily complete; n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Index number	Name	Data types used to determine reconstructed streamflows at flow-reconstruction site						
		Daily observed streamflows estimated from discrete streamflows		Monthly values of observed streamflow at site			Drainage-area adjustment	
		At partial-record station (USGS station number)	Period of discrete streamflow measurements, in water years (USGS station number)	USGS station number of streamgage	Period of calculated monthly reconstructed flows, in water years	Period of calculated sectional monthly reconstructed flows	Reconstructed monthly flows at flow-reconstruction site (index number)	Sectional reconstructed monthly flows at flow-reconstuction site (index number)
Recon32	Stone House Brook at outlet of Butler Reservoir , N.J.	n.a.	n.a.	n.a.	n.a.	n.a.	Beaver Brook at outlet[1] of Splitrock Reservoir near Hibernia, N.J. (Recon39)	n.a.
Recon33	Posts Brook above Wanaque diversion near Wanaque, N.J.	Posts Brook diversion to[2] Wanaque Reservoir near Wanaque, N.J. (01387020) and Posts Brook below diversion to Wanaque Reservoir near Wanaque, N.J. (01387021)	1935–2014 (01387020) and 2005–2014 (01387021)	n.a.	n.a.	n.a.	n.a.	n.a.
Recon34	Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (diversion)	Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (01387020)	1935–2014	n.a.	n.a.	n.a.	n.a.	n.a.
Recon35	Ramapo River at Pompton Lakes, N.J.	n.a.	n.a.	01388000	1922–2010	2006–2010	n.a.	n.a.
Recon36	Haycock Brook at outlet of Point View Reservoir near Pompton Plains, N.J.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Ramapo River at Pompton Lakes, N.J. (Recon35sec)
Recon37	Pompton River at Pompton Plains, N.J.	n.a.	n.a.	[3]01388500	1923–2010	n.a.	n.a.	n.a.

[1]Beaver Brook at outlet of Splitrock Reservoir, N.J. (Recon39), is in the Rockaway River subbasin.

[2]Sum of estimated daily flows at Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (01387020), and Posts Brook below diversion to Wanaque Reservoir near Wanaque, N.J. (01387021).

[3]Monthly observed streamflows were estimated from records of corresponding streamflow of one or more nearby gages.

Table 18. Streamflow adjustment terms used to calculate monthly reconstructed flows at selected flow-reconstruction sites in the subbasin of the Pompton River, northern New Jersey, during water years 1922–2010.

[No reservoir storage in the Pompton River subbasin was included; n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Selected flow-reconstruction site		Components of streamflow adjustment terms			
Index number	Name (USGS station number of streamgage at site)	Selected diversions moving water into Pompton River subbasin (diversion index)	Selected diversions moving water out of Pompton River subbasin (diversion index)	Combined adjustments from upstream subbasins at the indicated flow reconstruction sites (flow-reconstruction site index number)	Reconstruction equation[1]
Recon35	Ramapo River at Pompton Lakes, N.J. (01388000)	n.a.	(Div15) Ramapo River diversion at Pompton Lakes, N.J. (Div16) Ramapo River diversion to Oradell Reservoir at Pompton Lakes, N.J.	n.a.	mRecon35 = m01388000 + Div15 + Div16
Recon37	Pompton River at Pompton Plains, N.J. (01388500)[2]	n.a.	(Div14) Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (Div15) Ramapo River diversion at Pompton Lakes, N.J. (Div16) Ramapo River diversion to Oradell Reservoir at Pompton Lakes, N.J. (Div17) Point View Reservoir diversion to Passaic Valley Water Commission at Wayne, N.J.	Pequannock River subbasin (Recon26adj) Pequannock River at Macopin Intake Dam, N.J. Wanaque River subbasin (Recon31adj) Wanaque River at Wanaque, N.J.	mRecon37 = m01388500 + (+ Div14 + Div15 + Div16 + Div17) + mRecon26adj + mRecon31adj

[1] "m" denotes monthly flow.

[2]Monthly observed streamflows were estimated from records of corresponding streamflow at one or more nearby gages.

Table 19. Streamflow adjustment terms and upstream streamgages used to calculate sectional monthly reconstructed flows at selected flow-reconstruction sites in the subbasins of the Pompton River and main stem Passaic River, northern New Jersey, during water years 1922–2010.

[Size of area determined from drainage areas to each streamgage; n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Selected flow-reconstruction sites		Sectional monthly reconstructed flow is the sectional observed streamflows adjusted for diversions				Reconstruction equation for sectional flow[2]
		Sectional observed flow is the difference between (a) the sum of monthly observed streamflows at the selected upstream streamgages and (b) monthly observed streamflow at the selected flow-reconstruction site		Streamflow adjustment terms		
Index number	Name (USGS station number of streamgage at site)	Area[1] (square miles)	Selected upstream streamgages (USGS station number / index number)	Selected diversions moving water into area contributing sectional monthly reconstructed flows to site (diversion index)	Selected diversions moving water out of area contributing sectional monthly reconstructed flows to site (diversion index)	
Pompton River						
Recon35sec	Ramapo River at Pompton Lakes, N.J. (01388000)	40.0	Pompton River near Mahwah, N.J. (01387500/ n.a.)	n.a.	(Div15) Ramapo River diversion at Pompton Lakes, N.J. (Div16) Ramapo River diversion to Oradell Reservoir at Pompton Lakes, N.J.	mRecon35sec = (m01388000 - m01387500) + Div15 + Div16
Main stem Passaic River						
Recon49sec	Passaic River at Pine Brook, N.J. (01381900)	89.6	Passaic River near Chatham, N.J. (01379500/Recon46); Canoe Brook at diversion near Summit, N.J. (01379530/Recon48); Rockaway River below Reservoir at Boonton, N.J. (01381000/Recon42); and Whippany River at Morristown, N.J. (01381500/Recon45).	n.a.	(Div21) Passaic River diversion near Summit, N.J.	mRecon49sec = (m01381900 - (m01379500 + m01379530 + m01381000 + m01381500)) + Div21
Recon53sec	Passaic River at Little Falls, N.J. (01389500)	58.0	Passaic River at Pine Brook, N.J. (01381900/Recon49) and Pompton River at Pompton Plains, N.J. (01388500/Recon37)	n.a.	(Div23) Pompton River diversion to Wanaque Reservoir at Two Bridges, N.J. (Div24) Pompton River diversion to Oradell Reservoir at Two Bridges, N.J. (Div25) Pompton River diversion to Passaic Valley Water Commission at Two Bridges, N.J. (Div26) Passaic River diversion at Little Falls, N.J.	mRecon53sec = (m01389500 - (m01381900 + m01388500)) + (Div23 + Div24 + Div25 + Div26)

[1]Area that is upstream from the flow-reconstruction site and downstream from selected streamgages.

[2] "m" denotes monthly flow.

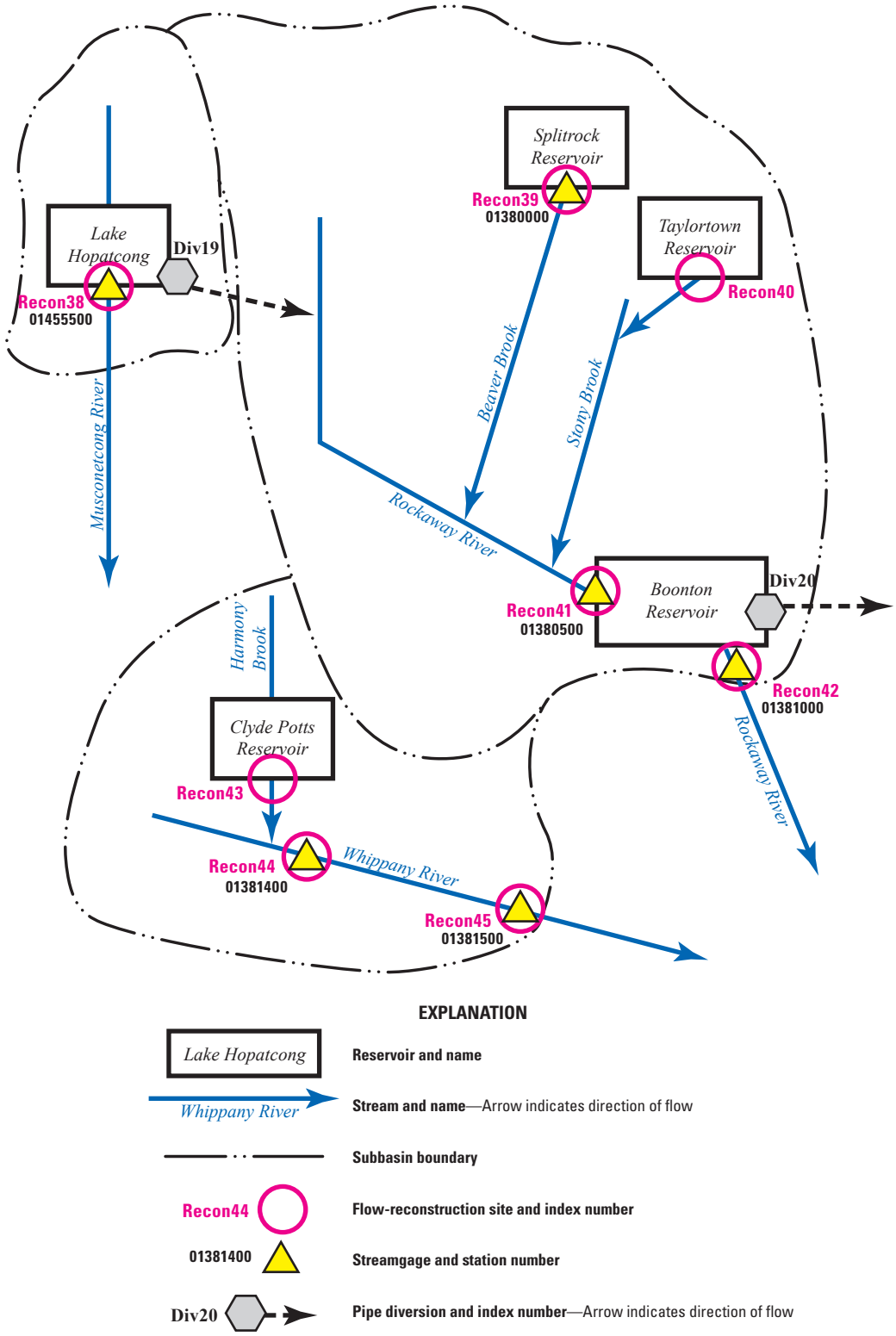

Figure 14. Streamflow in the subbasins of the Rockaway, Musconetcong, and Whippany Rivers, northern New Jersey.

Table 20. Data types used to reconstruct flows at sites in the subbasins of Rockaway River, Musconetcong River, and Whippany River, northern New Jersey during water years 1922–2010.

[Periods of calculated monthly reconstructed flows are not necessarily complete; n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Flow-reconstruction site		Data types used to determine reconstructed streamflows at flow-reconstruction site		
		Monthly values of observed streamflow at site		Drainage-area adjustment of reconstructed monthly flows at flow-reconstruction site (index number)
Index number	Name	USGS station number of streamgage at site	Period of calculated monthly reconstructed flows, in water years	
Musconetcong River				
Recon38	Musconetcong River at outlet of Lake Hopatcong, N.J	01455500	1961–2010	n.a.
Rockaway River				
Recon39	Beaver Brook at outlet of Splitrock Reservoir near Hibernia, N.J.	01380000	1976–1988	n.a.
Recon40	Stony Brook tributary at outlet of Taylortown Reservoir, N.J.	n.a.	n.a.	Beaver Brook at outlet of Splitrock Reservoir near Hibernia, N.J. (Recon39)
Recon41	Rockaway River above Reservoir at Boonton, N.J.	01380500	1938–2010	n.a.
Recon42	Rockaway River below Reservoir at Boonton, N.J.	01381000	1922–2010	n.a.
Whippany River				
Recon43	Harmony Brook at outlet of Clyde Potts Reservoir near Brookside, N.J.	n.a.	n.a.	Whippany River near Morristown, N.J. (Recon44)
Recon44	Whippany River near Morristown, N.J.	01381400	1996–2010	n.a.
Recon45	Whippany River at Morristown, N.J.	01381500	1922–2010	n.a.

Table 21. Streamflow adjustment terms used to calculate monthly reconstructed flows at selected flow-reconstruction sites in the subbasins of the Musconetcong, Rockaway, and Whippany Rivers, northern New Jersey, during water years 1922–2010.

[n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Selected flow-reconstruction site		Components of streamflow adjustment terms			Reconstruction[1] equation
Index number	Name (USGS station number of streamgage at site)	Selected diversions moving water into drainage area of flow-reconstruction site (diversion index)	Selected diversions moving water out of drainage area of flow-reconstruction site (diversion index)	Changes in monthly storage in indicated reservoirs	
Musconetcong River					
Recon38	Musconetcong River at outlet of Lake Hopatcong, N.J (01455500)	n.a.	(Div19) Lake Hopatcong diversion to Rockaway River, N.J.	Lake Hopatcong	mRecon38= m01455500 + Div19 + Hopatcong
Rockaway River					
Recon39	Beaver Brook at outlet of Splitrock Reservoir near Hibernia, N.J. (01380000)	n.a.	n.a.	Splitrock Reservoir	mRecon39= m01380000 + Splitrock
Recon41	Rockaway River above Reservoir at Boonton, N.J. (01380500)	(Div19) Lake Hopatcong diversion to Rockaway River, N.J.	n.a.	Splitrock Reservoir	mRecon41= m01380500 + Splitrock – Div19
Recon42	Rockaway River below Reservoir at Boonton, N.J. (01381000)	(Div19) Lake Hopatcong diversion to Rockaway River, N.J.	(Div20) Boonton Reservoir diversion at Boonton, N.J.	Splitrock Reservoir Boonton Reservoir	mRecon42= m01381000 + Boonton + Splitrock – Div19 + Div20
Whippany River					
Recon44	Whippany River near Morristown, N.J. (01381400)	n.a.	n.a.	n.a.	mRecon44 = m01381400
Recon45	Whippany River at Morristown, N.J. (01381500)	n.a.	n.a.	n.a.	mRecon45 = m01381500

[1] "m" denotes monthly flow.

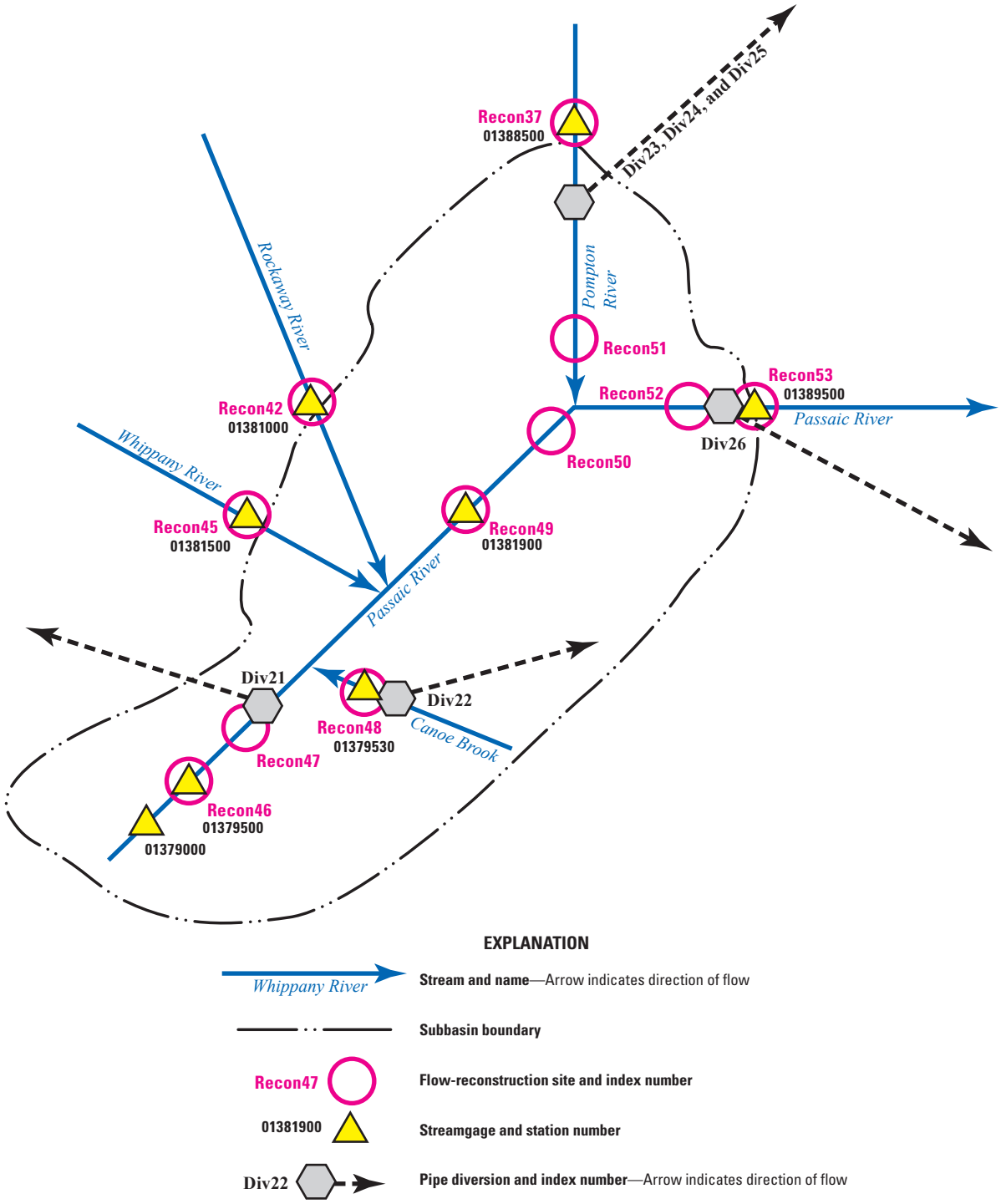

Figure 15. Streamflow in the Main Stem Passaic River subbasin, northern New Jersey.

Table 22. Data types used to estimate reconstructed flows at selected sites in the Main Stem Passaic River subbasin, northern New Jersey, water years 1922–2010.

[n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Flow-reconstruction site		Data types used to determine reconstructed streamflows at flow-reconstruction site				
		Monthly values of observed streamflow at site		Drainage-area adjustment of reconstructed monthly flows at flow-reconstruction site (index number)	Sum of monthly reconstructed flows at upstream sites and sectional monthly reconstructed flows at site	
Index number	Name	USGS station number of streamgage at site	Period of calculated monthly reconstructed flows, in water years		Upstream sites	Determination of sectional monthly reconstructed flows at site
Recon46	Passaic River near Chatham, N.J.	[1]01379500	1922–2010	n.a.	n.a.	n.a.
Recon47	Passaic River at diversion near Summit, N.J.	n.a.	n.a.	Passaic River near Chatham, N.J. (Recon46)	n.a.	n.a.
Recon48	Canoe Brook at diversion near Summit, N.J.	01379530	1966–2010	n.a.	n.a.	n.a.
Recon49	Passaic River at Pine Brook, N.J.	n.a.	n.a.	n.a.	See table 19	See table 19
Recon50	Passaic River at Two Bridges, N.J.	n.a.	n.a.	n.a.	Passaic River at Pine Brook, N.J. (Recon49)	Drainage-area adjustment of sectional monthly reconstructed flows at Passaic River at Little Falls, N.J. (Recon53)
Recon51	Pompton River at Two Bridges, N.J.	n.a.	n.a.	n.a.	Pompton River at Pompton Plains, N.J. (Recon37)	Drainage-area adjustment of sectional monthly reconstructed flows at Passaic River at Little Falls, N.J. (Recon53)
Recon52	Passaic River above Beatties Dam at Little Falls, N.J.	n.a.	n.a.	Passaic River at Little Falls, N.J. (01389500/ Recon53)	n.a.	n.a.
Recon53	Passaic River at Little Falls, N.J.	01389500	1922–2010	n.a.	n.a.	n.a.

[1]Monthly observed streamflows were estimated from records of corresponding streamflow of one or more nearby gages.

Table 23. Streamflow adjustment terms used to calculate monthly reconstructed flows at selected flow-reconstruction sites in the subbasin of the Main Stem Passaic River, northern New Jersey, during water years 1922–2010.

[n.a., not applicable; N.J., New Jersey; USGS, U.S. Geological Survey]

Selected flow-reconstruction site		Period of calculated monthly reconstructed flows, in water years (may be incomplete)	Components of streamflow adjustment terms			Reconstruction[1] equation
Index number	Name (USGS station number of streamgage at site)		Diversions of water into Main Stem Passaic River subbasin (diversion index number)	Diversions of water out of Main Stem Passaic River subbasin (diversion index number)	Combined adjustments from upstream subbasins at the indicated flow reconstruction sites (flow-reconstruction index number)	
Recon46	Passaic River[2] near Chatham, N.J. (01379500)	1922–2010	n.a.	n.a.	n.a.	mRecon46 = m01379500
Recon48	Canoe Brook at diversion near Summit, N.J. (01379530)	1966–2010	n.a.	(Div22) Canoe Brook diversion near Summit, N.J.	n.a.	mRecon48 = m01379530 + Div22
Recon49	Passaic River at Pine Brook, N.J. (01381900)	2006–2010	n.a.	(Div21) Passaic River diversion near Summit, N.J. (Div22) Canoe Brook diversion near Summit, N.J.	Rockaway River subbasin (Recon42adj) Rockaway River below Reservoir at Boonton, N.J. Whippany River subbasin (Recon45adj) Whippany River at Morristown, N.J.	mRecon49 = m01381900 + (Div21 + Div22) + mRecon42adj + mRecon45adj
Recon53	Passaic River at Little Falls, N.J. (01389500)	1922–2010	n.a.	(Div21) Passaic River diversion near Summit, N.J. (Div22) Canoe Brook diversion near Summit, N.J. (Div23) Pompton River diversion to Wanaque Reservoir at Two Bridges, N.J. (Div24) Pompton River diversion to Oradell Reservoir at Two Bridges, N.J. (Div25) Pompton River diversion to Passaic Valley Water Commission at Two Bridges, N.J. (Div26) Passaic River diversion at Little Falls, N.J.	Pompton River subbasin (Recon37adj) Pompton River at Pompton Plains, N.J. Rockaway River subbasin (Recon42adj) Rockaway River below Reservoir at Boonton, N.J. Whippany River subbasin (Recon45adj) Whippany River at Morristown, N.J.	mRecon53 = m01389500 + (mRecon37adj + mRecon42adj + mRecon45adj) + (Div21mod + Div22mod + Div23 + Div24 + Div25 + Div26)

[1] "m" denotes monthly flow.

[2] Monthly observed streamflows were estimated from records of corresponding streamflow of one or more nearby gages.

Limitations and Assessment of Reconstructed Flows

The implications of the methods used to determine monthly and daily reconstructed flows and the reconstructed flows themselves are discussed in the following sections. Information about the data release associated with this report is then presented.

Calculation of Monthly Reconstructed Flows from Observed Streamflow, Changes in Reservoir Storage, and Surface-Water Diversions

The calculated monthly reconstructed flows in this report (and, by extension, daily reconstructed flows determined from them) include only the effects on streamflow resulting from reservoir storage and surface-water withdrawals by purveyors. Other effects, such as those from groundwater diversions and point-source discharges, are not included. The absence of these effects means that reconstructed flows may be overestimated downstream from groundwater withdrawals or may be underestimated downstream from wastewater-treatment-plant discharges. More information on groundwater withdrawals and point-source discharges can be found in Storck and Nawyn (2001).

At some sites, negative values of monthly reconstructed flows were calculated by adjusting monthly observed streamflows for diversions and changes in reservoir storage. These negative values nearly always occurred under low-flow conditions and likely are due to errors in streamflow or in the terms used to determine the flow adjustment terms. Negative values also may be due to the failure to include all diversions or reservoirs in the calculations. Daily reconstructed flows determined from negative monthly reconstructed flows were set to zero.

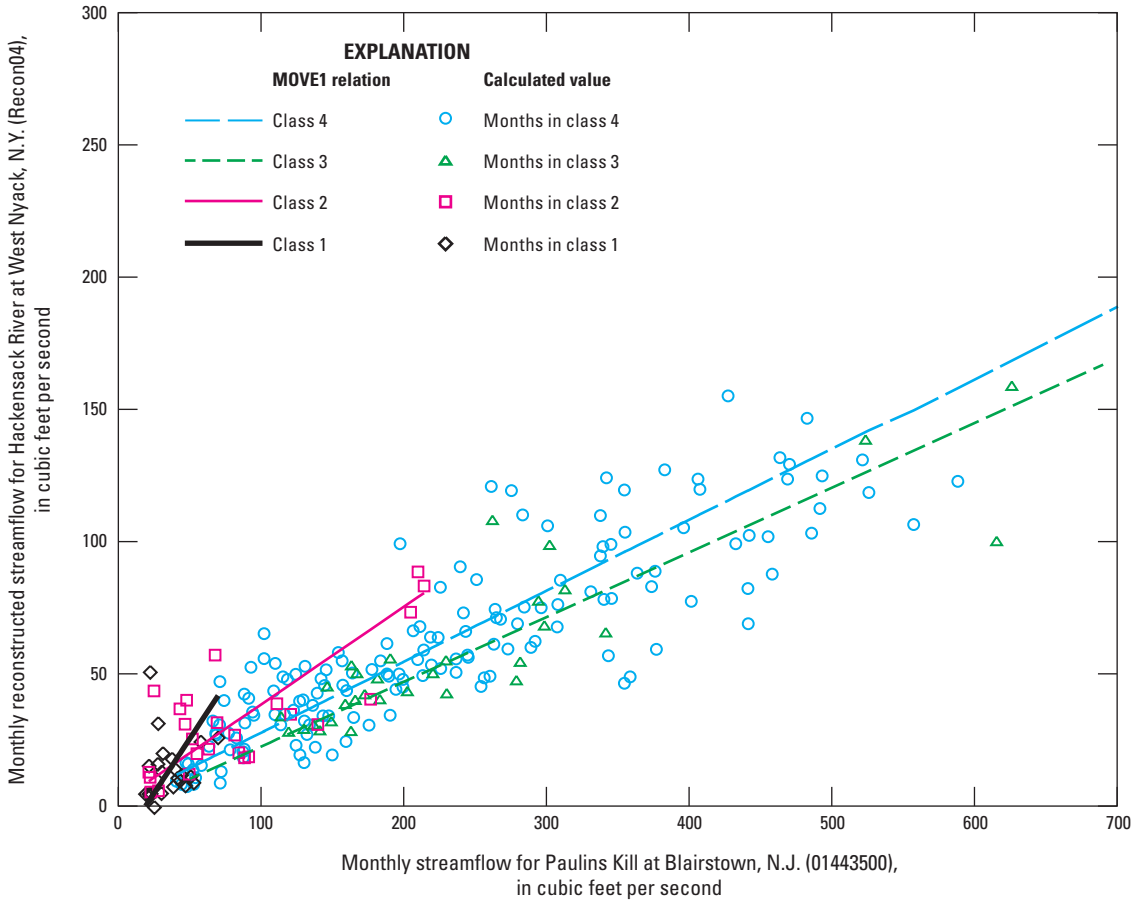

Figure 16. Monthly reconstructed streamflows in the Hackensack River at West Nyack, N.Y. (01376800/Recon04) as a function of monthly streamflows in Paulins Kill at Blairstown, N.J. (01443500), water years 1959–79.

Estimation of Monthly Reconstructed Flows and Sectional Monthly Reconstructed Flows from Relations with Monthly Observed Flows at Index Gages

Hydrologic classes were used to group months in order to develop more accurate relations between calculated monthly reconstructed streamflows (or sectional reconstructed flows) and monthly observed streamflows at each index gage. An example of the relation for each hydrologic class between calculated reconstructed monthly flows at the Hackensack River at West Nyack, N.J. (Recon04), and monthly observed streamflows at Paulins Kill at Blairstown, N.J. (01443500), during water years 1959–79 is shown in figure 16.

As a second example, the relation between sectional monthly reconstructed streamflows at Passaic River at Little Falls, N.J. (Recon53), and monthly observed streamflows at Paulins Kill at Blairstown, N.J. (01443500), for water years 2006–10 is shown in figure 17. Only one relation was developed for these data.

The use of these relations to estimate monthly reconstructed flow may produce values greater or less than actual values if there have been changes in streamflow resulting from changes in basin characteristics between the period of calculated reconstructed flows used to create the relations and the period for which monthly reconstructed flows were estimated. Streamflow can be affected by changes in such basin characteristics as land use, point-source discharges, and groundwater withdrawals. This bias in estimated monthly reconstructed flows is also present in the daily reconstructed flows determined from them.

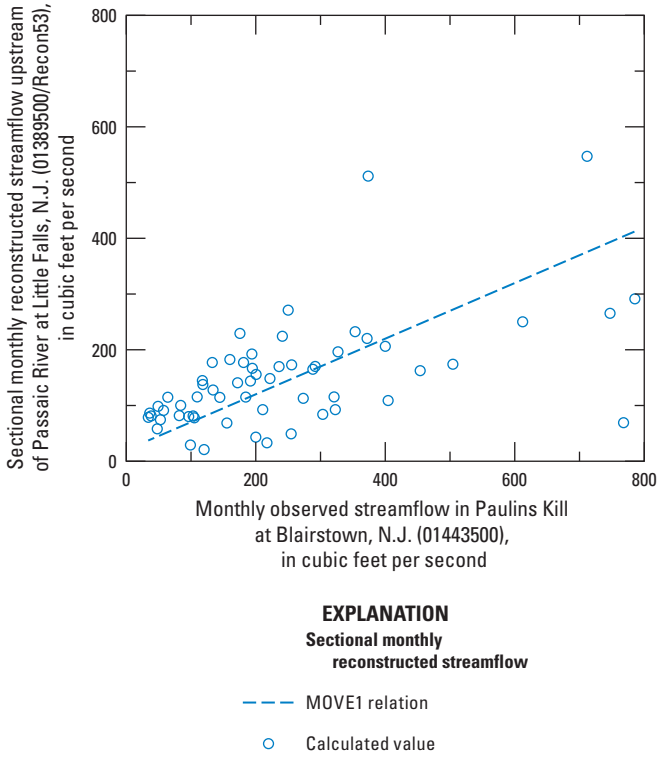

Figure 17. Sectional monthly reconstructed flows upstream from the Passaic River at Little Falls, N.J. (01389500/Recon53), as a function of monthly observed streamflow in the Paulins Kill at Blairstown, N.J. (01443500), water years 2006–10.

Determination of Daily Reconstructed Flows from Disaggregation of Monthly Reconstructed Flows

Disaggregation streamgages used to determine daily reconstructed flows at each site were selected to be as physically close as possible to the flow-reconstruction site and to have a drainage area similar to that of the site. However, given that there are differences between characteristics of the basin of the disaggregation streamgage and that of the flow-reconstruction site, it is likely that the predicted day of peak daily reconstructed flow may differ from the day of the actual peak.

Daily and Monthly Reconstructed Flows Determined from Discrete Streamflow Measurements at Partial-Record Stations

Daily and monthly reconstructed streamflows determined from discrete measurements of observed streamflows at partial-record stations are likely less accurate than corresponding values determined from monthly observed streamflows measured at a streamgage because the former are based on far less information. Examples of relations between discrete streamflow measurements and daily observed streamflows at Paulins Kill at Blairstown, N.J. (01443500), are shown in appendix 3.

In addition, daily flows estimated from relations between discrete streamflow measurements and daily observed flows at index gages on days when streamflow is changing are likely to be less accurate than on those days when streamflow is constant. Measurements of discrete streamflow at most of the partial-record stations in this study (table 6) were made in order to define streamflow under base-flow conditions; these discrete measurements were likely made on days when streamflows were rather constant.

Assessment of Reconstructed Streamflows

The final reconstructed streamflow records were reviewed by comparing flow gained between sites going downstream during the study period 1922–2010. Most sites generally exhibit reasonable, consistent gains between sites throughout the study period. Notable exceptions include indications of flow lost instead of gained through Boonton Reservoir (fig. 14) and flow lost instead of gained on the Passaic River in the area between Pine Brook and Pompton Plains (Recon 49 and Recon 37) down to Little Falls (Recon53) (fig. 15).

In comparing reconstructed flows upstream and downstream from Boonton Reservoir (Recon41 and Recon42), the data indicate relatively small fluctuations in gains and losses through the reservoir until the 1960s. From the late 1960s to the early 1980s, there is a long period of steady streamflow losses through the reservoir, followed by a long period of steady gains from the 1980s through 2010. There were substantial groundwater withdrawals in the subbasin that are not accounted for in these reconstructed streamflows. However, it is more likely that the gains and losses indicated by the reconstructed streamflows are an artifact of the inaccuracies of the reported storage in the Boonton Reservoir.

In the lower part of the Main Stem Passaic River subbasin, between Pine Brook (Recon 49), Pompton Plains (Recon37), and Little Falls (Recon53), it appears that the gains are not consistent, with variable periods of gaining and losing flow. There are several factors to consider when interpreting the results for this particular subbasin. The intervening flows between sites (Recon49, Recon37, and Recon53) were computed using the estimation of sectional flows, which were based on MOVE1 relations of intervening flow with flow at index gages. So, the first possibility is that the MOVE1 relations do not accurately reflect the hydrology of this section of the reach. However, this sectional flow estimation approach was chosen purposefully in an attempt to reflect the effects of the wetlands in this part of the subbasin, which are not present in the upper part of the Main Stem Passaic River subbasin. Using a simple drainage area adjustment would artificially "force" a steady, consistent gain and would not reflect the different basin characteristics in this part of the reach. Owing to the enhanced effects of evapotranspiration from increased vegetation in wetlands, it is common for streams to change from gaining to losing, depending on season and groundwater availability. So, it could be that the MOVE1 relation actually does a good job of representing this natural phenomenon over time. Another factor to consider is the amount of groundwater withdrawals that occur between sites, especially in the area upstream from Pine Brook (Recon49). Because groundwater flows were not accounted for in this reconstruction, they too may have an effect on the amount of water gain expected between sites.

Data Release

The data release associated with this report (Hickman, 2018) contains the following information: (1) some observed streamflow and diversion data that are not readily available to the public, (2) some estimated values of observed streamflows and monthly rates of transfer, (3) calculated monthly reconstructed streamflows, and (4) all monthly and daily reconstructed streamflows. Datasets are listed below.

1. Monthly hydrologic class determined for streams in northern New Jersey and southeastern New York, water years 1922–2010.
2. Unpublished and furnished daily observed streamflows at two streamgages in northern New Jersey, October 1965–September 2001.
3. Estimated daily observed streamflows at six partial-record stations in northern New Jersey and southeastern New York, water years 1922–2010.
4. Monthly observed streamflows at selected streamgages estimated from records at other streamgages in northern New Jersey, water years 1922–2010.
5. End-of-month storage in Lake Hopatcong at Landing, N.J. (01455400), February 1887– September 2011.
6. Daily rates of transfer from diversions from Lake Hopatcong, Lake Wawayanda, and Pompton River during selected periods.
7. Monthly rates of transfer by two selected New Jersey American diversions, January 1965–December 1973.
8. Estimated monthly rates of transfer to Oradell Reservoir from three North Jersey District Water Supply Commission diversions, February 1985–September 2010.
9. Calculated monthly reconstructed streamflows at sites in northern New Jersey and southeastern New York, water years 1922–2010.
10. Equations used to estimate monthly reconstructed streamflows from calculated monthly reconstructed streamflows and monthly streamflows at index gages.
11. Monthly reconstructed streamflows at sites in northern New Jersey and southeastern New York, water years 1922–2010.
12. Daily reconstructed streamflows at flow-reconstruction sites in northern New Jersey and southeastern New York, water years 1922–2010.

Summary

A study was conducted by the U.S. Geological Survey, in cooperation with the New Jersey Department of Environmental Protection, to provide reconstructed streamflows for use in the RiverWare model. Methods and data used to estimate daily reconstructed streamflows in selected subbasins in northern New Jersey and southeastern New York used in the study are presented in this report. These subbasins contain one or more surface-water diversions (some not currently operating) by water purveyors or the New Jersey Department of Environmental Protection.

Reconstructed flows are those that would have occurred without the effects of changes in reservoir storage or

surface-water diversions by water purveyors. Reconstructed flows were determined for 53 flow-reconstruction sites.

Reconstructed flows are used as input to the RIVERWARE streamflow accounting model developed by the New Jersey Department of Environmental Protection. Results of model can be used to determine the value of safe yield for water diversions by selected water purveyors in New Jersey.

Daily reconstructed flows at 46 sites were determined from reconstructed monthly flows adjusted for reservoir storage and surface-water diversions. Missing monthly reconstructed flows were estimated from relations between calculated values and monthly flows at index gages. Daily reconstructed flows were determined from the monthly reconstructed flows by using the records for selected streamgages. Daily reconstructed flows at six sites were estimated from relations between discrete streamflow measurements at partial-record stations and daily streamflows at index gages. Streamflows at some partial-record stations represent water diverted from one stream channel to another.

The methods used in this study for flow reconstruction were not intended to provide a full accounting of water use and its implications on flow, but rather were intended to be used as one of many possible approaches to produce a dataset for further evaluation of water use. The daily reconstructed streamflows are available in a data release (Hickman, 2018). The data release includes selected data used for calculations so that comparisons of reconstructed flows can be made between sites.

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Appendix 1. Estimation of Monthly Observed Streamflows at Selected Streamgages

Monthly observed streamflows for each of four selected streamgages were estimated from records of corresponding streamflow for one or more nearby streamgages. The selected streamgages are in the subbasins of the Saddle River, Pompton River, and Main Stem Passaic River.

Saddle River Subbasin

Monthly observed streamflows were estimated for the streamgages at Saddle River at Upper Saddle River, N.J. (01390450), and Saddle River below Hohokus Brook at Paramus, N.J. (01391102), (table 5, fig. 10, in the body of the report). Streamflows for the Saddle River at Upper Saddle River, N.J. (01390450), were estimated from the record of streamflows at the streamgage at Saddle River at Ridgewood, N.J. (01390500), using equations 1-1 and 1-2. For those months when streamflow at the gage at Ridgewood (01390500) was less than or equal to 50 cubic feet per second (ft^3/s), flows at the gage at Upper Saddle River (01390450) were estimated from drainage-area adjustment of flows at Ridgewood by using equation 1-1. For months when streamflow at the gage at Ridgewood (01390500) was greater than 50 ft^3/s, the monthly streamflows at the gage at Upper Saddle River (01390450) were estimated using equation 1-2. Equation 1-2 was developed from corresponding monthly observed streamflows at the two gages using the Maintenance of Variance Extension type 1 (Hirsch, 1982) described in appendix 5.

$$m01390450 = m01390500 \times \left(\frac{10.9}{21.6} \right) \tag{1-1}$$

$$m01390450 = \left(m01390500 \times 0.723 \right) - 11.1 \tag{1-2}$$

where

$m01390450$ is monthly observed streamflow at Saddle River at Upper Saddle River, N.J. (01390450), in cubic feet per second; and

$m01390500$ is monthly observed streamflow at Saddle River at Ridgewood, N.J. (01390500), in cubic feet per second.

Monthly observed streamflows at the streamgage at Saddle River below Hohokus Brook at Paramus, N.J. (01391102), were estimated from the drainage-area adjustment of monthly streamflows at Saddle River at Lodi, N.J. (01391500), (table 5, fig. 10, in the body of the report). This relation is shown in equation 1-3.

$$m01391102 = m01391500 \times \left(\frac{43.3}{54.6} \right) \tag{1-3}$$

where

$m01391102$ is monthly observed streamflow at Saddle River below Hohokus Brook at Paramus, N.J. (01391102), in cubic feet per second; and

$m01391500$ is monthly observed streamflow at Saddle River at Lodi, N.J. (01391500), in cubic feet per second.

Pompton River Subbasin

Monthly observed streamflows in the Pompton River at Pompton Plains, N.J. (01388500), were estimated by summing corresponding streamflows from three upstream streamgages and the estimated local contribution of streamflow downstream from these gages (table 5, fig. 13,

in the body of the report). The three upstream streamgages are the Pequannock River at Macopin Intake Dam, N.J. (01382500); Wanaque River at Wanaque, N.J. (01387000); and Ramapo River at Pompton Lakes, N.J. (01388000). The local streamflow contribution, determined using equation 1-4, was based on the difference between observed streamflows on the Ramapo River near Mahwah, N.J. (01387500), and at Pompton Lakes, N.J. (01388000), after adjustment for the diversions at Pompton Lakes (Div15 and Div16 in table 4 in the body of the report). Equation 1-5 was used to calculate monthly observed streamflows in the Pompton River at Pompton Plains, N.J. (01388500).

$$Local = \frac{\left(\left(m01388000 - m01387500\right) + Div15 + Div16\right)}{\left(160 - 120\right)} \times \left(355 - \left(63.7 + 90.4 + 160\right)\right) \quad (1\text{-}4)$$

$$m01388500 = \left(m01382500 + m01387000 + m01388000\right) + Local \quad (1\text{-}5)$$

where

Local is monthly observed streamflow at the Pompton River at Pompton Plains, N.J. (01388500), originating downstream from the streamgages on the Pequannock River at Macopin Intake Dam, N.J. (01382500), Wanaque River at Wanaque, N.J. (01387000), and Ramapo River at Pompton Lakes, N.J. (01388000), in cubic feet per second;

Div15 is rate of transfer from Ramapo River at Pompton Lakes to Wanaque Reservoir, in cubic feet per second;

Div16 is rate of transfer from Ramapo River at Pompton Lakes to Oradell Reservoir, in cubic feet per second;

*m*01382500 is monthly observed streamflow at Pequannock River at Macopin Intake Dam, N.J. (01382500), in cubic feet per second;

*m*01387000 is monthly observed streamflow at Wanaque River at Wanaque, N.J. (01387000), in cubic feet per second;

*m*01387500 is monthly observed streamflow at Ramapo River near Mahwah, N.J. (01387500), in cubic feet per second; and

*m*01388000 is monthly observed streamflow at Ramapo River at Pompton Lakes, N.J. (01388000), in cubic feet per second.

Main Stem Passaic River Subbasin

Monthly observed streamflows at the streamgage on the Passaic River near Chatham, N.J. (01379500), were estimated using the drainage-area adjustment of corresponding streamflows at the gage upstream at Passaic River near Millington, N.J. (01379000), (fig.15, table 5, in the body of the report). Equation is

$$m01379500 = m01379000 \times \left(\frac{100}{55.4}\right) \quad (1\text{-}6)$$

where

*m*01379500 is monthly observed streamflow at Passaic River near Chatham, N.J. (01379500), in cubic feet per second; and

*m*01379000 is monthly observed streamflow at Passaic River at Millington, N.J. (01391000), in cubic feet per second.

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Appendix 2. Calculation of Monthly Observed Streamflows in Beaver Brook at the Outlet of Splitrock Reservoir from Furnished Data

Monthly observed streamflows at the streamgage on Beaver Brook at the outlet of Splitrock Reservoir, N.J. (01380000), in the Rockaway River subbasin were calculated using furnished records of stage readings at the outlet of the reservoir (table 5, fig.14, in the body of the report). Once-daily readings of stage were provided by Jersey City Bureau of Water during the period 1976–89. Measurements of streamflow were periodically made by the U.S. Geological Survey (USGS), and a stage-discharge rating curve was developed. Streamflows were determined using the once-daily, discrete stage readings provided by the Jersey City Bureau of Water and the rating curve developed by the USGS. The estimated observed flows are provided in the data release associated with this report (Hickman, 2018).

An examination of time-series plots of the daily streamflows in Beaver Brook at the outlet of Splitrock Reservoir, N.J. (01380000), revealed that the many of the daily discrete streamflows were unchanged from the streamflow on the previous day (fig. 2-1). These daily streamflows were divided into two groups—"unchanged" streamflows, which are the same as on the previous day, and "changed" streamflows, which are different from the value on the previous day.

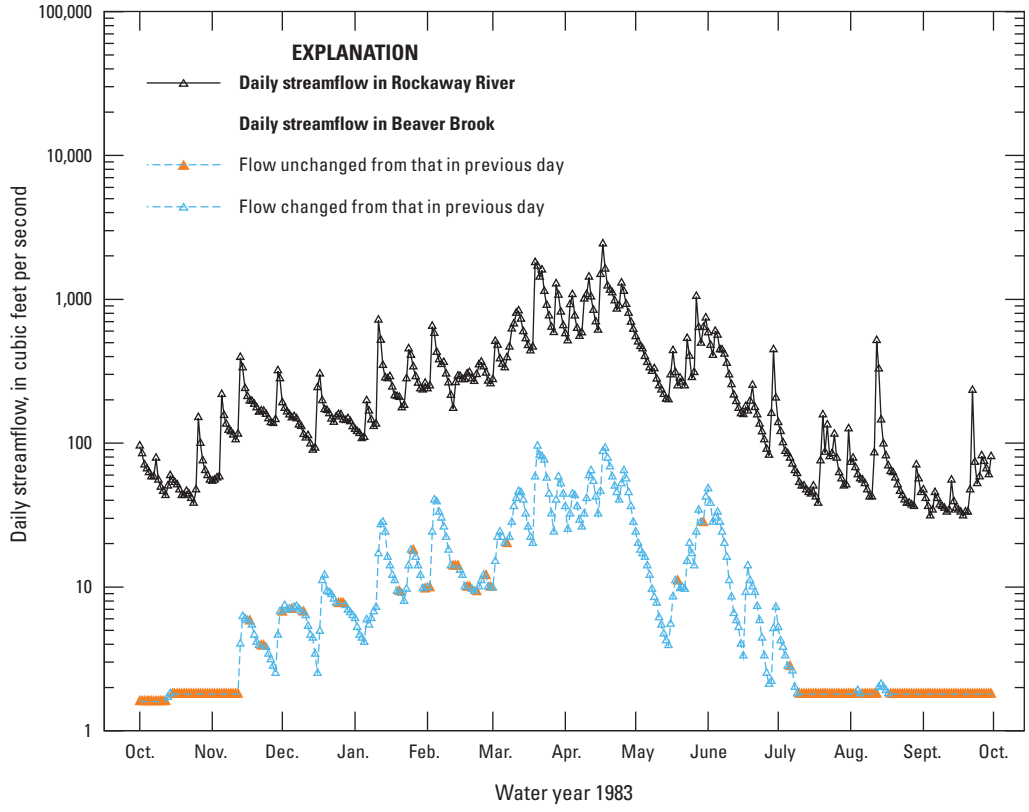

Figure 2-1. Time-series plots of daily streamflows in Beaver Brook at outlet of Splitrock Reservoir, N.J. (01380000), and in Rockaway River above Reservoir at Boonton, N.J. (01380500), water year 1983.

The variation over time of the daily "changed" streamflows in Beaver Brook at the outlet of Splitrock Reservoir, N.J. (01380000), is similar to the variation shown by the daily streamflows measured at the downstream streamgage on the Rockaway River above Reservoir at Boonton, N.J. (01380500), during 1976–83 (fig. 2-2). The schematic diagram of the subbasin is shown in figure 14 in the body of the report. This similarity provides some support for the accuracy of the daily "changed" streamflows in Beaver Brook (01380000).

As a result of this comparison, monthly observed streamflows in Beaver Brook at the outlet of Splitrock Reservoir, N.J. (01380000), were calculated only for those months in which there were five or fewer "unchanged" daily streamflows. Monthly reconstructed flows for this site, Beaver Brook at the outlet of Splitrock Reservoir, N.J. (Recon39), were calculated by summing monthly observed streamflow and changes in monthly storage in Splitrock Reservoir (table 21 in the body of the report).

Monthly reconstructed flows in Beaver Brook at the outlet of Splitrock Reservoir, N.J. (Recon39), were calculated from monthly observed flows and changes in storage in Splitrock Reservoir. On the basis of flow per square mile, most monthly reconstructed flows at Beaver Brook at outlet of Splitrock Reservoir, N.J. (Recon39), are similar to the monthly observed streamflows in Rockaway River above Reservoir at Boonton, N.J. (01380500). The streamflows reflect the similar characteristics of the two basins and lend confidence to the use of the record even though the record was not published by the USGS.

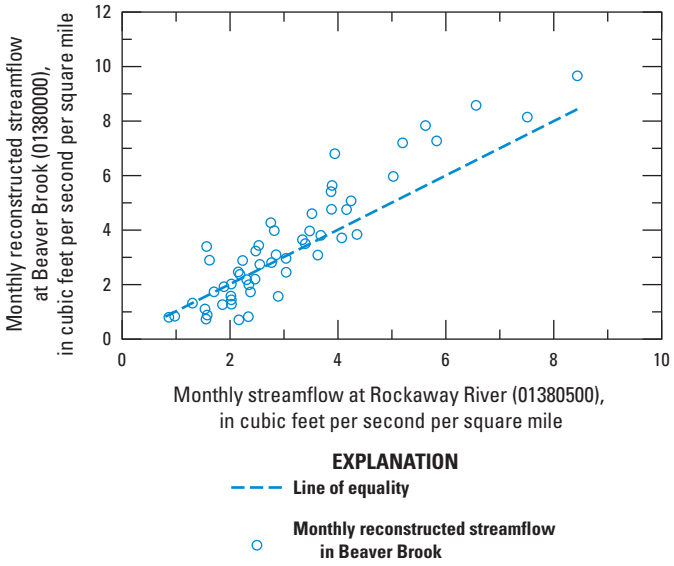

Figure 2-2. Selected monthly reconstructed streamflows per square mile in Beaver Brook at outlet of Splitrock Reservoir, N.J. (01380000), as a function of observed streamflow per square mile in Rockaway River above Reservoir at Boonton, N.J. (01380500), water years 1976–83.

References Cited

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Appendix 3. Estimation of Observed Daily Streamflow at Six Partial-Record Stations

Observed daily streamflows at six partial-record stations were estimated from relations between discrete streamflow measurements at each partial-record station and daily streamflows at each of the index gages. The relations took one of two forms. For most partial-record stations, a linear relation with the following form was developed:

$$q_{prstation} = \left(q_{index} \times slope\right) + intercept \quad (3\text{-}1)$$

where

$q_{prstation}$ is discrete streamflow measurement at partial-record station, in cubic feet per second;

q_{index} is daily streamflow at index gage on day of discrete measurement, in cubic feet per second;

slope is slope of relation, unitless; and

intercept is intercept of relation, in cubic feet per second.

As an example, measured discrete streamflows and predicted values from equation 3-1, as a function of daily observed streamflows at Paulins Kill at Blairstown, N.J. (01443500), are shown in figure 3-1 for two partial-record stations on Posts Brook in the Pompton River subbasin.

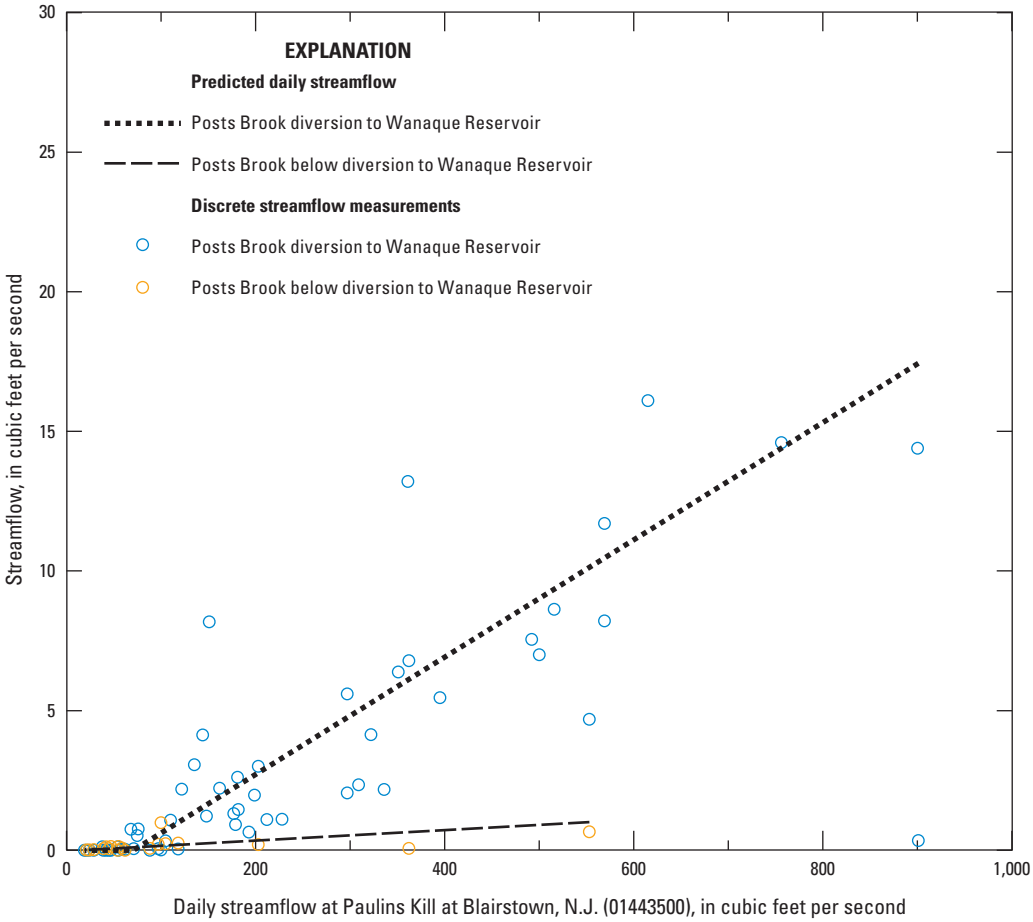

Figure 3-1. Discrete streamflow measurements at Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (01387020), and Posts Brook below Wanaque diversion near Wanaque, N.J. (01387021), as a function of daily streamflow at Paulins Kill at Blairstown, N.J. (01443500), 1935–2014.

Daily observed streamflows at the Auxiliary outlet of Upper Greenwood Lake at Moe, N.J. (01368720), were estimated with a different form of equation. A "semi-logarithmic" relation was used, as defined below.

$$q_{prstation} = \left(\log\left(q_{index}\right) \times slope\right) + intercept \tag{3-2}$$

where

$q_{prstation}$ is discrete streamflow measurement at partial-record station, in cubic feet per second;

log is base-10 logarithm;

q_{index} is daily streamflow at index gage on day of discrete measurement, in cubic feet per second;

slope is slope of relation, unitless; and

intercept is intercept of relation, in cubic feet per second.

A plot of the discrete streamflow measurements at the Auxiliary outlet of Upper Greenwood Lake at Moe, N.J. (01368720), as a function of daily observed streamflows in Paulins Kill at Blairstown, N.J. (01443500), is given in figure 3-2.

Relations between discrete measurements and daily flows at each index gage were determined by use of the Maintenance of Variance Extension type 1 (MOVE1) (Hirsch, 1982) as described in appendix 5. Equation slope and intercepts are given in table 3-1.

Daily observed flows at each partial-record station were estimated using the developed MOVE1 equations and the daily flows in the Paulins Kill at Blairstown, N.J (01443500), except for days of missing daily flows in water year 1977 (table 3-1). For daily flows missing in water year 1977, daily observed flows estimated with equations and daily flows at the Pequest River at Pequest, N.J. (01445500), were used. Estimated daily values less than zero were set to zero.

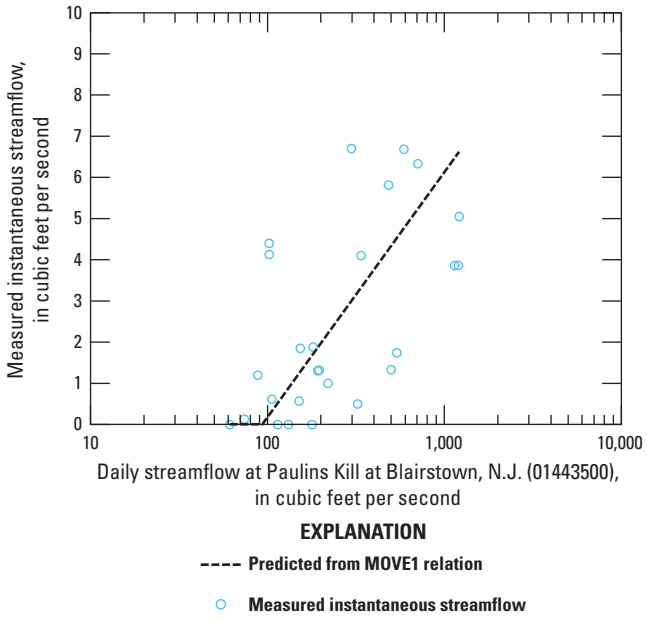

Figure 3-2. Discrete streamflow measurements at Auxiliary outlet of Upper Greenwood Lake at Moe, N.J. (01368720), as a function of daily streamflow in Paulins Kill at Blairstown, N.J. (01443500), 1975–80.

Table 3-1. Relations between discrete streamflow measurements at selected partial-record stations and daily streamflows at each of the index streamgages, northern New Jersey and southeastern New York.

[Straight and semi-logarithmic are defined in the text.; N.J., New Jersey; N.Y., New York; USGS, U.S. Geological Survey]

Partial-record station (USGS station number)	Type of relation with index streamgage	Period of discrete streamflow measurements, in water years		Number of discrete streamflow measurements	Slope and intercept for equation between discrete streamflow measurements and daily streamflows at each index gage			
					Paulins Kill at Blairstown, N.J. (01443500)		Pequest River at Pequest, N.J. (01445500)	
		First	Last		Slope	Intercept	Slope	Intercept
Hirshfeld Brook								
Hirshfeld Brook at New Milford, N.J. (01378520)	Straight	1965	2010	33	0.012	1.155	0.017	0.939
Double Kill								
Double Kill at Wawayanda, N.J. (01368820)	Straight	1998	2012	58	0.064	-2.378	0.109	-6.211
Long House Creek								
Auxiliary outlet of Upper Greenwood Lake at Moe, N.J. (01368720)	Semi-logarithmic	1975	1980	29	5.967	-11.770	6.038	-11.456
Long House Creek below Cascade Lake, N.Y. (01368722)	Straight	1973	1976	18	0.086	-6.292	0.104	-8.033
Pompton River								
Posts Brook diversion to Wanaque Reservoir near Wanaque, N.J. (01387020)	Straight	1935	2014	56	0.021	-1.488	0.027	-1.782
Posts Brook below Wanaque diversion near Wanaque, N.J. (01387021)	Straight	2005	2014	19	0.002	-0.032	0.002	-0.029

References Cited

Hirsch, R.M., 1982, A comparison of four streamflow record extension techniques: Water Resources Research, v. 18, no. 4, p. 1081–1088.

Appendix 4. Estimation of Monthly Transfer Rates of the Three Pipe Diversions Used by the North Jersey District Water Supply Commission to Transfer Water to Oradell Reservoir

Since February 1985, the North Jersey District Water Supply Commission (NJDWSC) has transferred water to Oradell Reservoir in the Hackensack River subbasin (fig. 10 in the body of the report) by use of one or more of three pipe diversions (table 4 in the body of the report). The Wanaque Reservoir diversion to Oradell Reservoir, N.J. (Div13), transferred water from the Wanaque River subbasin (fig. 12 in the body of the report). The Ramapo River diversion to Oradell Reservoir at Pompton Lakes, N.J. (Div16), transferred water from the Pompton River subbasin (fig. 13 in the body of the report). The Pompton River diversion to Oradell Reservoir at Two Bridges, N.J. (Div24), transferred water from the Main Stem Passaic River subbasin (fig. 15 in the body of the report). The total amount of water transferred to Oradell Reservoir from all these diversions was available (New Jersey Geological and Water Survey, 2013), but the rates for each of the individual diversions were not.

The rates of monthly transfers to Oradell Reservoir from each of the three diversions (Div13, Div16, and Div24) were estimated from the total water sent to Oradell Reservoir (New Jersey Geological and Water Survey, 2013), based on two types of information.

The first type of information consists of dates of initial use of each diversion to transfer water to Oradell Reservoir. According to the Bauersfeld and others (1990), the water transferred to Oradell Reservoir by the North Jersey District Water Supply Commission from 1985 through water year 1988 was entirely from the Ramapo River (Div16). Also, according to NJDWSC (Dag Madara, NJDWSC, written commun. 2015), the earliest diversion from the Wanaque Reservoir to Oradell (Div13) occurred in July 1987—a diversion of 20.7 million gallons per day on one day—during an assumed test of the system; this diversion was not used again until July 1988.

The second type of information came from a suggestion by Dag Madara (NJDWSC, written commun., 2015) to estimate the diversions in use in each month from a comparison of (1) the amount of water transferred to Oradell Reservoir by the NJDWSC (sum of Div13, Div16, and Div24) and (2) the amount of water transferred to the Wanaque Reservoir from the Ramapo and Pompton Rivers (sum of Div15 and Div23).

For those months when the amount of water transferred to Oradell Reservoir from all sources (sum of Div13, Div16, and Div24) was less than or equal to the amount of water transferred from the Ramapo and Pompton Rivers to the Wanaque Reservoir (sum of Div15 and Div23), the water transferred to the Oradell was assumed to have come entirely from the two rivers and none from the Wanaque Reservoir. For these months, the water transferred from each river to the Oradell Reservoir (Div16 and Div24) was calculated by prorating the water transferred to Oradell on the basis of the amounts of water transferred from each river to the Wanaque Reservoir (Div15 and Div23). The amount of water transferred to Wanaque Reservoir from each river was then reduced by the amount estimated to have been transferred from that river to the Oradell Reservoir. The amount of water assumed to have been transferred from the Wanaque Reservoir to the Oradell Reservoir (Div13) was set to zero.

If the amount of water transferred by the NJDWSC to Oradell Reservoir (sum of Div13, Div16, and Div24) was greater than the amount of water reported to have been transferred to the Wanaque Reservoir from the Ramapo and Pompton Rivers (sum of Div15 and Div23), then all water was assumed to have come from the Wanaque Reservoir. Diversions to Oradell Reservoir from the Ramapo and Pompton Rivers (Div15 and Div24) were set to zero.

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Appendix 5. Maintenance of Variance Extension Type 1

The Maintenance of Variance Extension type 1 (MOVE1) was proposed as a method to estimate missing values of streamflow at one streamgage from the relation between streamflows at that streamgage (dependent) and corresponding streamflows at another streamgage (independent) over the same period by Hirsch (1982). The equation given below has been modified to show separate terms for slope and intercept. The equation estimates streamflows at the dependent streamgage using streamflows at the independent streamgage. The equation is determined from a series of concurrent streamflow measurements at the independent index gage and at the dependent streamgage.

$$estQdep(i) = Qind(i) \times \left[\frac{S(Qdep)}{S(Qind)} \right]_{slope} + \left[m(Qdep) - \left(\frac{S(Qdep)}{S(Qind)} \right) \times m(Qind) \right]_{intercept} \quad (5\text{-}1)$$

where

$estQdep\ (i)$	is estimated streamflow at dependent streamgage during period, i;
$Qind\ (i)$	is streamflow at dependent streamgage during period, i;
$S\ (Qdep)$	is standard deviation of streamflows at dependent streamgage;
$S\ (Qind)$	is standard deviation of streamflows at independent streamgage;
$m\ \ (Qdep)$	is mean of streamflow at dependent streamgage; and
$m(Qind)$	is mean of streamflow at independent streamgage.

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Hirsch, R.M., 1982, A comparison of four streamflow record extension techniques: Water Resources Research, v. 18, no. 4, p. 1081–1088.

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