# Estimated Water Use and Availability in the Pawcatuck Basin, Southern Rhode Island and Southeastern Connecticut, 1995–99

By Emily C. Wild and Mark T. Nimiroski

Prepared in cooperation with the
Rhode Island Water Resources Board

Scientific Investigations Report 2004-5020

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# Contents

# Figures

# Tables

# Conversion Factors, Datums, Abbreviations and Acronyms

| Multiply | By | To obtain |
|---|---|---|
| acre | 4,047 | square meter ($m^2$) |
| acre | 0.4047 | hectare (ha) |
| foot (ft) | 0.3048 | meter (m) |
| foot squared ($ft^2$) | 0.3048 | meter squared ($m^2$) |
| foot squared per day ($ft^2/d$) | 0.09290 | meter squared per day ($m^2/d$) |
| gallons per day (gal/d) | 0.003785 | cubic meter per day ($m^3/d$) |
| mile (mi) | 1.609 | kilometer (km) |
| million gallons per day (Mgal/d) | 3,785 | cubic meters per day ($m^3/d$) |
| million gallons per day per square mile ($Mgal/d/mi^2$) | 1,462.1 | cubic meter per day per square kilometer ($m^3/d/km^2$) |
| square mile ($mi^2$) | 12.590 | square kilometer ($km^2$) |

Temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

$$°C=(°F-32)/1.8$$

Transmissivity: In this report, the unit of transmissivity is foot squared per day ($ft^2/d$).

To convert water use and availability data to cubic feet per second, multiply million gallons per day by 1.5466.

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD83).

| | |
|---|---|
| 7Q10 | 7-day, 10-year flow |
| ABF | Aquatic Base Flow |
| FGDC | Federal Geographic Data Committee |
| GIS | Geographic Information System |
| HAP | Hunt–Annaquatucket–Pettaquamscutt |
| HUC | Hydrologic Unit Code |
| IWR-MAIN | Institute of Water Resources, Municipal and Industrial Needs |
| MAGIC | Map and Geographic Information Center |
| MCD | Minor Civil Division |
| NCDC | National Climatic Data Center |
| NEWUDS | New England Water-Use Data System |
| NHD | National Hydrography Dataset |
| NOAA | National Oceanic and Atmospheric Administration |
| NRCS | Natural Resources Conservation Service |
| RIDEM | Rhode Island Department of Environmental Management |
| RIEDC | Rhode Island Economic Development Corporation |
| RIGIS | Rhode Island Geographic Information System |
| RIPDES | Rhode Island Pollutant Discharge Elimination System |
| SCS | Soil Conservation Service |
| SIC | Standard Industrial Classification |
| STRMDEPL | Streamflow depletion computer program |
| URI | University of Rhode Island |
| USDA | United States Department of Agriculture |
| USEPA | United States Environmental Protection Administration |
| USGS | United States Geological Survey |
| UWRI | United Water of Rhode Island |
| WBD | Watershed Boundary Dataset |
| WSO | Weather Station Observatory |
| WWTF | Wastewater-Treatment Facility |

# Estimated Water Use and Availability in the Pawcatuck Basin, Southern Rhode Island and Southeastern Connecticut, 1995–99

By Emily C. Wild and Mark T. Nimiroski


## Abstract

In 1988, the Pawcatuck Basin (302.4 square miles) in southern Rhode Island (245.3 square miles) and southeastern Connecticut (57.12 square miles) was defined as a sole-source aquifer for 14 towns in southern Rhode Island and 4 towns in southeastern Connecticut. To determine water use and availability, the six subbasins in the Pawcatuck Basin were delineated on the basis of the surface- and ground-water system drainage areas. From 1995 through 1999, five major water suppliers in the basin withdrew an average of 6.768 million gallons per day from the aquifers. The estimated water withdrawals from minor water suppliers during the study period were 0.099 million gallons per day. Self-supplied domestic, industrial, commercial, and agricultural withdrawals from the basin averaged 4.386 million gallons per day. Water use in the basin averaged 7.401 million gallons per day. The average return flow in the basin was 7.855 million gallons per day, which included effluent from permitted facilities and self-disposed water users.

The PART program, a computerized hydrograph-separation application, was used for five selected index stream-gaging stations to determine water availability on the basis of the 75th, 50th, and 25th percentiles of the total base flow, the base flow minus the 7-day, 10-year flow criteria, and the base flow minus the Aquatic Base Flow criteria at the index stations. The differences in the surface- and ground-water system drainage areas in the summer were applied to the water availability calculated at the index stations and subbasins.

The base-flow contributions from sand and gravel deposits at the index stations were computed for June, July, August, and September, and applied to the percentage of surficial deposits at each index station. The base-flow contributions were converted to a per unit area at the station for the till, and for the sand and gravel deposits, and applied to the subbasins. The statistics used to estimate the gross yield of base flow, as well as subtracting out the two low-flow criteria, resulted in various water-availability values at each index station, which were present in the subbasin after applying the per unit area rates from the index station. The results from the Chipuxet and Arcadia stream-gaging stations were lowest in September at the 75th and 25th percentiles, and August flows were lowest for the summer at the 50th percentile. For the other three index stations, September flows were the lowest for the summer.

Because water withdrawals and use are greater during the summer than other times of the year, water availability in June, July, August, and September was assessed and compared to water withdrawals in the basin and subbasins. The ratios were calculated by using the water-availability flow scenarios at the 75th, 50th, and 25th percentiles for the subbasins, which are based on total water available from base-flow contributions from till deposits and sand and gravel deposits in the subbasins. For the study period, the withdrawals in August were higher than the other summer months. The ratios were close to one in August for the estimated gross yield and 7-day, 10-year flow criterion, and were close to one in September for the estimated Aquatic Base Flow criterion water-availability scenarios in the Pawcatuck Basin. The closer the ratio is to one, the closer the withdrawals are to the estimated water available, and the net water available decreases.

To determine the effects of streamflow depletion from continuous water withdrawals, the program STRMDEPL was used to simulate public wells and well fields at a constant pumping rate based on the 1999 summer average for each withdrawal, over a period of 180 days. The streamflow depletion was 86, 95, 93, 96, and 98 percent at 30 days for Kingston wells 1 and 2, Westerly well fields 1 and 2, and well 3, respectively.

A long-term hydrologic budget was calculated for the Pawcatuck Basin to identify and assess the basin and subbasin inflow and outflows. The water withdrawals and return flows used in the budget were from 1995 through 1999. For the hydrologic budget, it was assumed that inflow equals outflow, which resulted in 723.1 million gallons per day in the basin. The estimated inflows from precipitation and water return flow were 99 and 1 percent in the basin, respectively. The estimated outflows from evapotranspiration, streamflow, and water withdrawals were 43, 56, and 1 percent, respectively.

# Introduction

In 1988, the Pawcatuck Basin was designated as a sole-source aquifer by the U.S. Environmental Protection Agency (USEPA) for the 14 towns in southern Rhode Island and 4 towns in southeastern Connecticut in the basin (Federal Registrar, 1988). Based on data from the U.S. Census Bureau, southern Rhode Island had the highest population growth in the State, ranging from a 6.3 percent increase in Westerly to a 35 percent increase in Richmond, from the 1990 population census to the 2000 population census (Rhode Island Statewide Planning, 2001). Likewise, from 1995 through 1999, the estimated population growth was highest in the southern region in the State, ranging from a 3 percent increase in Hopkinton and Westerly to a 10 percent increase in Richmond (Rhode Island Economic Development Corporation, 2001). During the study period, there was an increase in the Rhode Island town populations in the basin, and an increase in withdrawals from the ground-water system. Water availability became a concern to the State during the 1999 drought, and further investigation was needed to assess water use and availability. During the summer of 1999, the average precipitation at the Kingston, RI, climatological station for June was only about 0.05 in., compared to the 30-year long-term average precipitation for June that was 3.936 in. (1971 through 2000). Because precipitation is a key component of ground-water infiltration (fig. 1), the rain deficiency, a period of little to no recharge, resulted in ground-water levels and streamflows dropping below the long-term averages throughout Rhode Island.

The U.S. Geological Survey (USGS), in cooperation with the Rhode Island Water Resources Board (RIWRB), began a series of water use and availability projects to better understand the relations between the water-use components (fig. 2) and the components of the hydrologic cycle (surface and ground water) during periods of little to no recharge. The Pawcatuck Basin was one of the first areas of concern to the State in the assessment of water use and availability because ground water is the principal water source for public suppliers and domestic users in the basin, (about 61 and 20 percent of the average annual water withdrawals, respectively, during the study period). The mission of the RIWRB is to serve as a water-sourcing agency to ensure future water availability for residential growth and economic development for all Rhode Islanders (Rhode Island Water Resources Board, 2003).

## Purpose and Scope

This report identifies the water-use components and assesses water use and availability in the Pawcatuck Basin and its six ground-water subbasins for periods of little to no recharge. To estimate water use, data were collected for the components of water use by ground-water subbasins for the towns and systems (supply and disposal) in the Pawcatuck Basin. The water withdrawals, users, and dischargers were organized and retrieved using the New England Water-Use Data System (NEWUDS) for the study period, calendar years 1995 through 1999. The report presents the results of the calculated water availability for the six subbasins with a method of determining ground-water discharge during streamflow-recession periods in the summer. To assess the streamflow and ground-water interactions, a streamflow-depletion program was run on five of the public supply wells and well fields near the streams. A basin water budget is presented in this report, and it was completed in order to summarize the components of the hydrologic cycle based on the long-term period of record and selected water-use components for the study period.

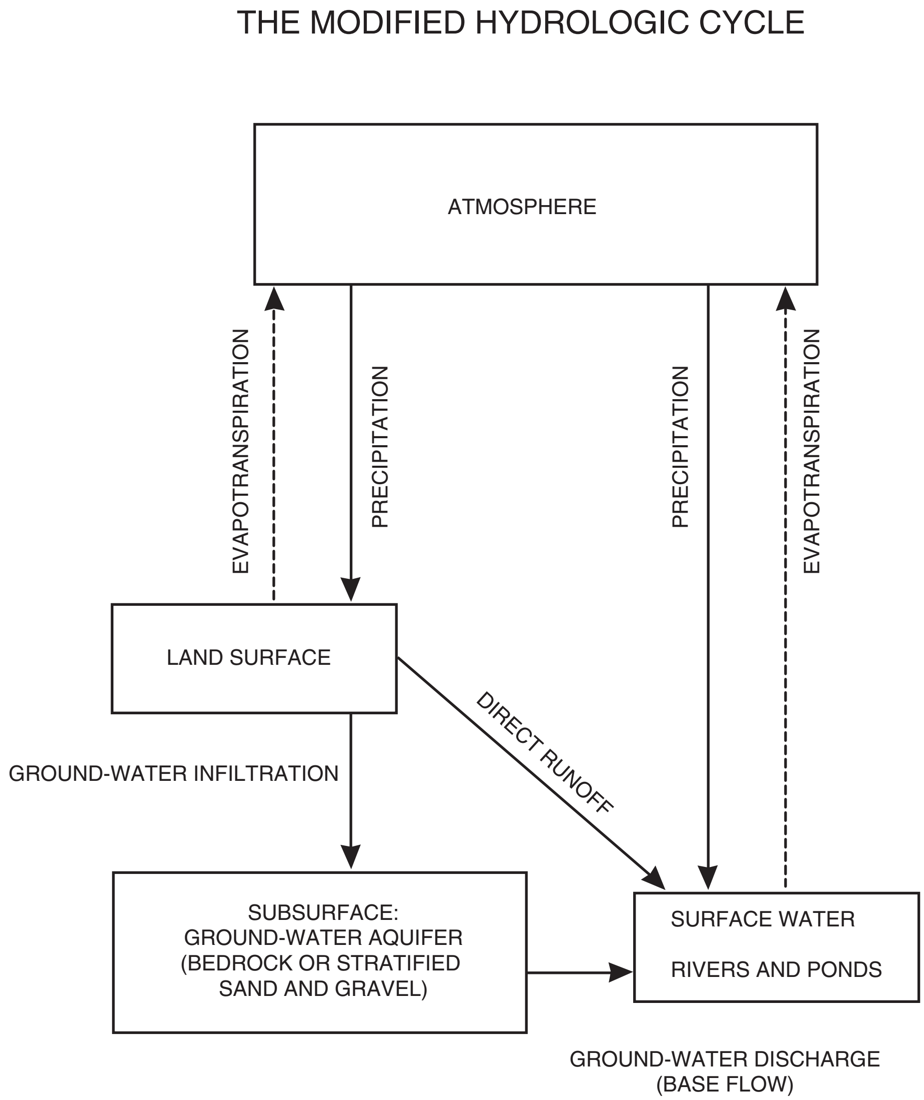



**Figure 1.** The modified hydrologic cycle.

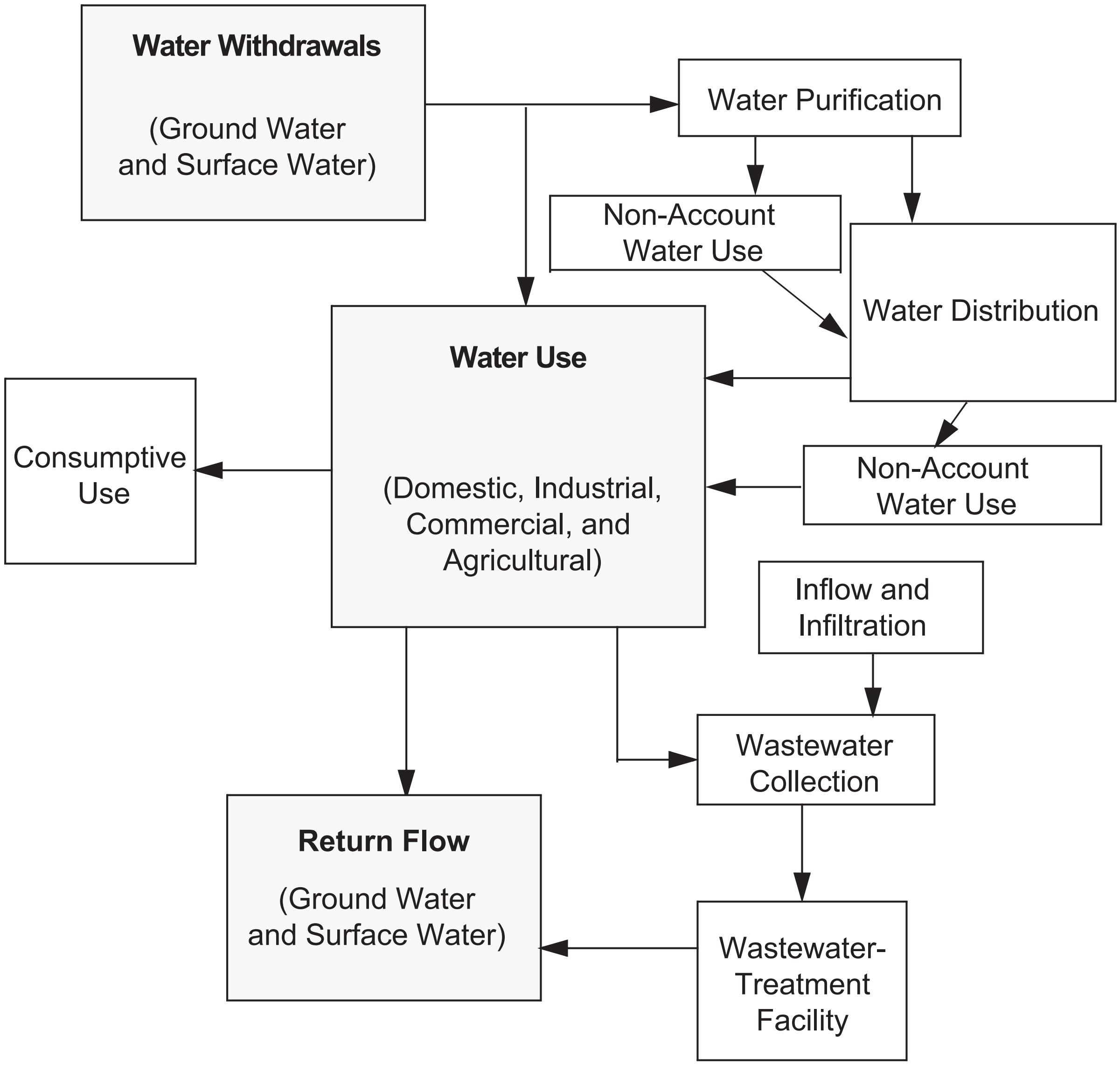



**Figure 2.** The components of water use.

## Previous Investigations

The U.S. Geological Survey has been collecting streamflow data through partial and continuous stream-gaging stations for the Pawcatuck Basin for over 60 years, and has been monitoring ground-water levels for more than 50 years. The data collected have been used for numerous hydrologic studies in the basin and its subbasins. Many studies have investigated the ground-water and surface-water resources and the water quality of the Pawcatuck Basin and its subbasins. The Pawcatuck is within the Ashaway, Carolina, Coventry Center, Hope Valley, Kingston, Oneco, Slocum, Voluntown, Watch Hill, and Wickford USGS quadrangles. The USGS has published these quadrangles in detailed thematic maps describing the surficial and bedrock geology (Feininger, 1962, 1965a, 1965b, 1965c; Hardwood, 1971a, 1971b; Moore, 1958, 1959, 1967; Power, 1957, 1959; and Schafer, 1961, 1965, 1968). In addition, the USGS has published basin studies that provide information on hydrologic characteristics of the surficial deposits (till and stratified sand and gravel deposits), ground-water models, precipitation, and streamflows in the Open-File Report, Professional Paper, Water-Resources Investigations Report, and Water-Supply Paper series (Allen and others, 1966; Barlow and Dickerman, 2001; Cervione and others, 1993; Crosby, 1905; DeSimone and Ostiguy, 1999; Dickerman, 1984; Dickerman and Ozbilgin, 1985; Dickerman and others 1990; Dickerman and others, 1997; Gonthier and others, 1974; Johnston and Dickerman, 1985; and Morrissey, 1989).

Previous investigations completed in cooperation with the Rhode Island Water Resources Board have been published in the Geological Bulletin, Ground-Water Map, Hydrologic Bulletin, Scientific Contribution and Water Information Series Report series. The Geologic Bulletins provide well records, lithologic logs, water-quality assessments, hydrologic characteristics of the surficial deposits (till and stratified sand and gravel deposits), and water-table information, and the information is provided by USGS quadrangle (Allen, 1953; Allen, 1956; Allen and others, 1963; Bierschenk, 1956; and Lang, 1961). Ground-Water Maps provide bedrock contours, water-table altitudes, well locations, and till and stratified sand and gravel deposits, and the information is provided by USGS quadrangle (Bierschenk and Hahn, 1959; Hahn, 1959; Johnson, 1961a; Johnson, 1961b; Johnson and others, 1960; LaSala and Hahn, 1960; Mason and Hahn, 1960; and Randal and others, 1960). Hydrologic Bulletins describe lithologic logs and historical aquifer tests (Lang and others, 1960). The Scientific Contribution series reports well records, and information on bedrock and surficial deposits (Allen and Jeffords, 1948). Water Information Series Reports describe the hydrologic characteristics by basin or subbasin (Dickerman, 1976; Dickerman and Johnston, 1977; Dickerman and Silva, 1980; Dickerman and others, 1989; Dickerman and Bell, 1993; and Kliever, 1995).

In addition to studies pertaining to surficial deposits in the basin and subbasins, information has been collected and compiled for the water use in the Pawcatuck Basin and statewide assessments (Craft and others, 1995; Horn, 2000; Horn and Craft, 1991; and Medalie, 1996). Information on major public water suppliers has been collected through written and oral communication from the Rhode Island Water Resources Board and major public water suppliers. The suppliers also prepare water-supply management plans that are submitted to the Rhode Island Water Resources Board, as a part of the State's Water Supply Systems Management Plan. Information on public disposal was collected (oral and written communication) from wastewater assessments that have been completed and submitted to the Rhode Island Department of Environmental Management (RIDEM), Office of Water Resources.

## Acknowledgments

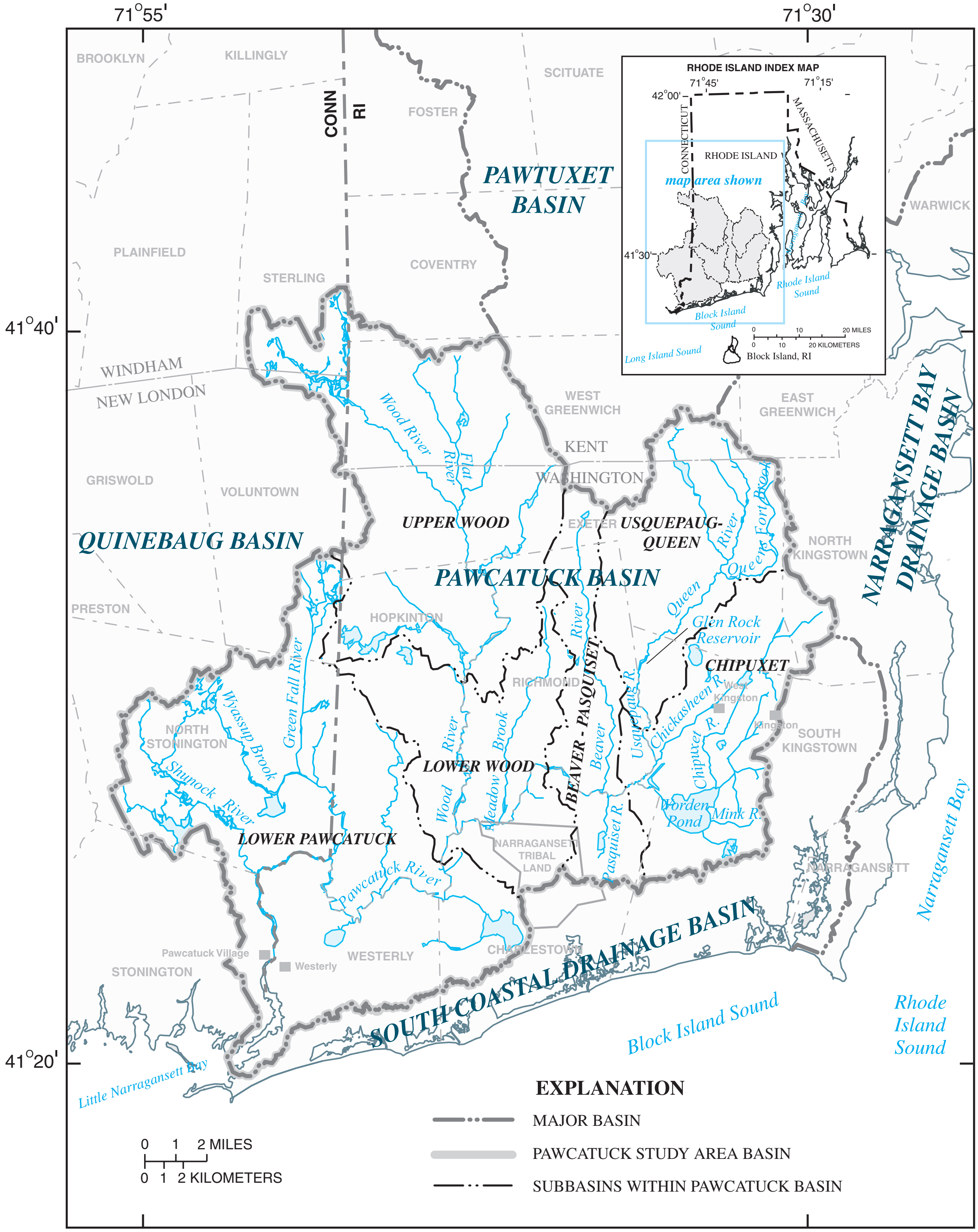
Original water-use withdrawal and discharge data were collected from the public water-supply districts, the RIDEM Office of Water Resources, individual wastewater-discharge facilities, and the Rhode Island Water Resources Board (RIWRB). The authors thank the following individuals for assisting in the data-collection process: Henry Meyer, Kingston Water District; the late Steve Pucino, University of Rhode Island (URI); Paul Corian, Westerly Water Department; Ron Richard, Richmond Water Supply System; Stanley Knox, United Water of Rhode Island (UWRI); Harold Storrs, Stonington Wastewater Facility; Aaron Mello, RIDEM Office of Water Resources; Clay Commons, Rhode Island Department of Health, Office of Drinking Water Quality; Amanda Aretz, Andrew Thorpe, and Carol Gannon, formerly of the U.S. Geological Survey; and Dennis Ventetuolo and Tomas Smieszek, U.S. Geological Survey.

# The Pawcatuck Basin

The Pawcatuck Basin is in southern Rhode Island and southeastern Connecticut (fig. 3). Land area in the basin totals approximately 302.4 $mi^2$, approximately 245.3 $mi^2$ of which is in Rhode Island and approximately 57.12 $mi^2$ of which is in Connecticut. The basin includes 10 Rhode Island towns and 4 Connecticut towns that are partially within the study area. In 1990, the basin population was approximately 61,481, and the estimated population during the study period was 66,528 (table 1). The Pawcatuck Basin is mostly hilly, with higher altitudes in the northwest. In Rhode Island, the highest altitude in the basin is Bald Hill at 629 ft in West Greenwich. The 10 principal ground-water reservoirs, or aquifers, in the basin are the Mink, Chipuxet, Usquepaug–Queen, Beaver–Pasquiset, Upper Wood, Lower Wood, Ashaway, Shunock, Bradford, and Westerly ground-water reservoirs (fig. 4). Ground-water aquifers are defined as areas of stratified sand and gravel deposits with a saturated thickness greater than 40 ft. For this study, the Pawcatuck Basin has been grouped into six subbasins: the Chipuxet, Usquepaug–Queen, Beaver–Pasquiset, Upper Wood, Lower Wood, and Lower Pawcatuck subbasins (fig. 4), and are based on the ground-water drainage areas.

Precipitation and temperature data for the climatological station at Kingston, RI, on the University of Rhode Island (URI) campus and the Providence WSO climatological station at the airport in Warwick, RI, were compiled using the monthly and annual summaries published in the series *Climatological Data New England* from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA). The total annual precipitation at the Kingston, RI, station from 1971 through 2000 was 49.94 in., and the average precipitation ranged from 3.308 in. (July) to 4.400 in. (August) for the summer. The total annual precipitation at the Kingston climatological station for the study period was 53.11 in., and the average monthly precipitation ranged from 2.728 in. (July) to 4.474 in. (September) for the summer. At the Providence WSO climatological station in Warwick, RI, the average annual precipitation for the 30-year period, 1971 through 2000, was 46.46 in., and the 30-year average monthly precipitation ranged from 3.169 in. (July) to 3.904 in. (August) for the summer. The average annual precipitation at Providence WSO for the study period was 43.91 in., and the average monthly precipitation ranged from 1.978 in. (July) to 4.014 in. (September) for the summer. The total annual temperature at the Kingston, RI, station from 1971 through 2000 was 49.94°F, and the average temperature ranged from 62.72°F (September) to 71.06°F (July) for the summer. The average annual temperature at the Kingston climatological station for the study period was 50.91°F, and the average monthly temperatures ranged from 63.74°F (September) to 71.88°F (July) for the summer. At the Providence WSO climatological station in Warwick, RI, the average annual temperature for the 30-year period, 1971 through 2000, was 51.13°F, and the 30-year average monthly temperatures ranged from 63.99°F (September) to 73.37°F (July) for the summer. The average annual temperature at Providence WSO for the study period was 51.84°F, and the average monthly temperatures ranged from 64.74°F (September) to 74.14°F (July) for the summer. Precipitation and temperature data for the climatological stations are summarized in table 2.

Land use was calculated by merging the Rhode Island Geographic Information Systems (RIGIS) land-use coverages and the Connecticut Map and Geographic Information Center (MAGIC) coverages with the subbasin-boundary coverages. Land-use area was used as a tool to aggregate commercial, industrial, and agricultural water-use estimates into the applicable towns, subbasins, and basin (table 3). For the Pawcatuck Basin, the total land-use area for commercial, industrial, and agricultural was 1.219 $mi^2$, 1.137 $mi^2$, and 25.98 $mi^2$, respectively. The commercial land-use area ranged from 0.060 $mi^2$ in the Lower Wood subbasin to 0.666 $mi^2$ in the Lower Pawcatuck subbasin. The industrial land-use area ranged from 0.011 $mi^2$ in the Usquepaug–Queen subbasin to 0.779 $mi^2$ in the Lower Pawcatuck subbasin. The agricultural land-use area ranged from 2.008 $mi^2$ in the Beaver–Pasquiset subbasin to 8.239 $mi^2$ in the Lower Pawcatuck subbasin. For water-supply districts, land-use area was used to aggregate the water-use categories by basin and subbasin (table 4). The total land-use area by public-supply district for commercial, industrial, and agricultural was 0.646 $mi^2$, 0.143 $mi^2$, and 1.416 $mi^2$, respectively, within the Pawcatuck Basin. The commercial land-use area ranged from 0.006 $mi^2$ to 0.536 $mi^2$, for the United Water of Rhode Island (UWRI) and Westerly Water Department service areas in the Pawcatuck Basin, respectively. The industrial land-use area ranged from 0.022 $mi^2$ to 0.097 $mi^2$, for the Richmond Water Supply and Westerly Water Department service areas in the Pawcatuck Basin, respectively. The agricultural land-use area ranged from 0.116 $mi^2$ to 0.841$mi^2$, for the Richmond Water Supply and Westerly Water Department service areas in the Pawcatuck Basin, respectively.




Base from U.S. Geological Survey, Connecticut MAGIC, and Rhode Island GIS data sets
Rhode Island state plane, 5176 fipzone
Horizontal datum is NAD 83
Source map scale 1:300,000

**Figure 3.** The Pawcatuck Basin and subbasins, southern Rhode Island and southeastern Connecticut.

**Table 1.** Total town populations by subbasins for 1990, estimated populations 1995–99, and estimated public and self supply and disposal populations in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[All towns are in Rhode Island unless otherwise noted. **Total populations in Rhode Island 1990:** From Rhode Island Geographic Information System (1991). **Estimated 1995–99 population:** From the Rhode Island Economic Development Corporation (2000). Total populations in Connecticut from 1990 are from the University of Connecticut Center for Geographic Information and Analysis (2000). Estimated 1995–99 population from the Connecticut Department of Health (1995, 1996, 1997, 1998, and 1999). --, not applicable]

| Towns | Population | | Estimated 1995–99 population | | | |
|---|---|---|---|---|---|---|
| | | | Supply | | Disposal | |
| | 1990 | Estimated 1995–99 | Public | Self | Public | Self |
| **Chipuxet Subbasin** | | | | | | |
| Charlestown | 239 | 264 | 34 | 230 | 28 | 236 |
| Exeter | 812 | 880 | 92 | 788 | 57 | 823 |
| North Kingstown | 668 | 728 | 596 | 132 | 7 | 721 |
| Richmond | 266 | 330 | 14 | 316 | -- | 330 |
| South Kingstown | 9,505 | 10,188 | 7,193 | 2,995 | 5,985 | 4,203 |
| Subbasin total | 11,490 | 12,390 | 7,929 | 4,461 | 6,077 | 6,313 |
| **Usquepaug–Queen Subbasin** | | | | | | |
| East Greenwich | 37 | 38 | 24 | 14 | 2 | 36 |
| Exeter | 2,866 | 3,107 | 164 | 2,943 | 92 | 3,015 |
| North Kingstown | 133 | 145 | 131 | 14 | 9 | 136 |
| Richmond | 652 | 808 | 78 | 730 | -- | 808 |
| South Kingstown | 434 | 465 | 15 | 450 | -- | 465 |
| West Greenwich | 212 | 240 | -- | 240 | -- | 240 |
| Subbasin total | 4,334 | 4,803 | 412 | 4,391 | 103 | 4,700 |
| **Beaver–Pasquiset Subbasin** | | | | | | |
| Charlestown | 1,403 | 1,553 | 162 | 1,391 | 135 | 1,418 |
| Exeter | 266 | 288 | 2 | 286 | -- | 288 |
| Richmond | 1,880 | 2,330 | 178 | 2,152 | -- | 2,330 |
| South Kingstown | 27 | 29 | 13 | 16 | 3 | 26 |
| Subbasin total | 3,576 | 4,200 | 355 | 3,845 | 138 | 4,062 |
| **Upper Wood Subbasin** | | | | | | |
| Coventry | 64 | 67 | 1 | 66 | -- | 67 |
| Exeter | 1,049 | 1,138 | 136 | 1,002 | 39 | 1,099 |
| Hopkinton | 1,938 | 2,189 | 150 | 2,039 | 108 | 2,081 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- |
| Richmond | 902 | 1,118 | 110 | 1,008 | -- | 1,118 |
| Sterling, CT | 380 | 444 | 45 | 399 | 70 | 374 |
| Voluntown, CT | 190 | 203 | 24 | 179 | 8 | 195 |
| West Greewich | 1,103 | 1,246 | 63 | 1,183 | 34 | 1,212 |
| Subbasin total | 5,626 | 6,405 | 529 | 5,876 | 259 | 6,146 |
| **Lower Wood Subbasin** | | | | | | |
| Charlestown | 1,223 | 1,354 | 40 | 1,314 | 6 | 1,348 |
| Hopkinton | 1,460 | 1,650 | 233 | 1,417 | 110 | 1,540 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- |
| Richmond | 1,650 | 2,045 | 123 | 1,922 | -- | 2,045 |
| Voluntown, CT | -- | -- | -- | -- | -- | -- |
| Subbasin total | 4,333 | 5,049 | 396 | 4,653 | 116 | 4,933 |

**Table 1.** Total town populations by subbasins for 1990, estimated populations 1995–99, and estimated public and self supply and disposal populations in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.—Continued

[All towns are in Rhode Island unless otherwise noted. **Total populations in Rhode Island 1990:** From Rhode Island Geographic Information System (1991). **Estimated 1995–99 population:** From the Rhode Island Economic Development Corporation (2000). Total populations in Connecticut from 1990 are from the University of Connecticut Center for Geographic Information and Analysis (2000). Estimated 1995–99 population from the Connecticut Department of Health (1995, 1996, 1997, 1998, and 1999). --, not applicable]

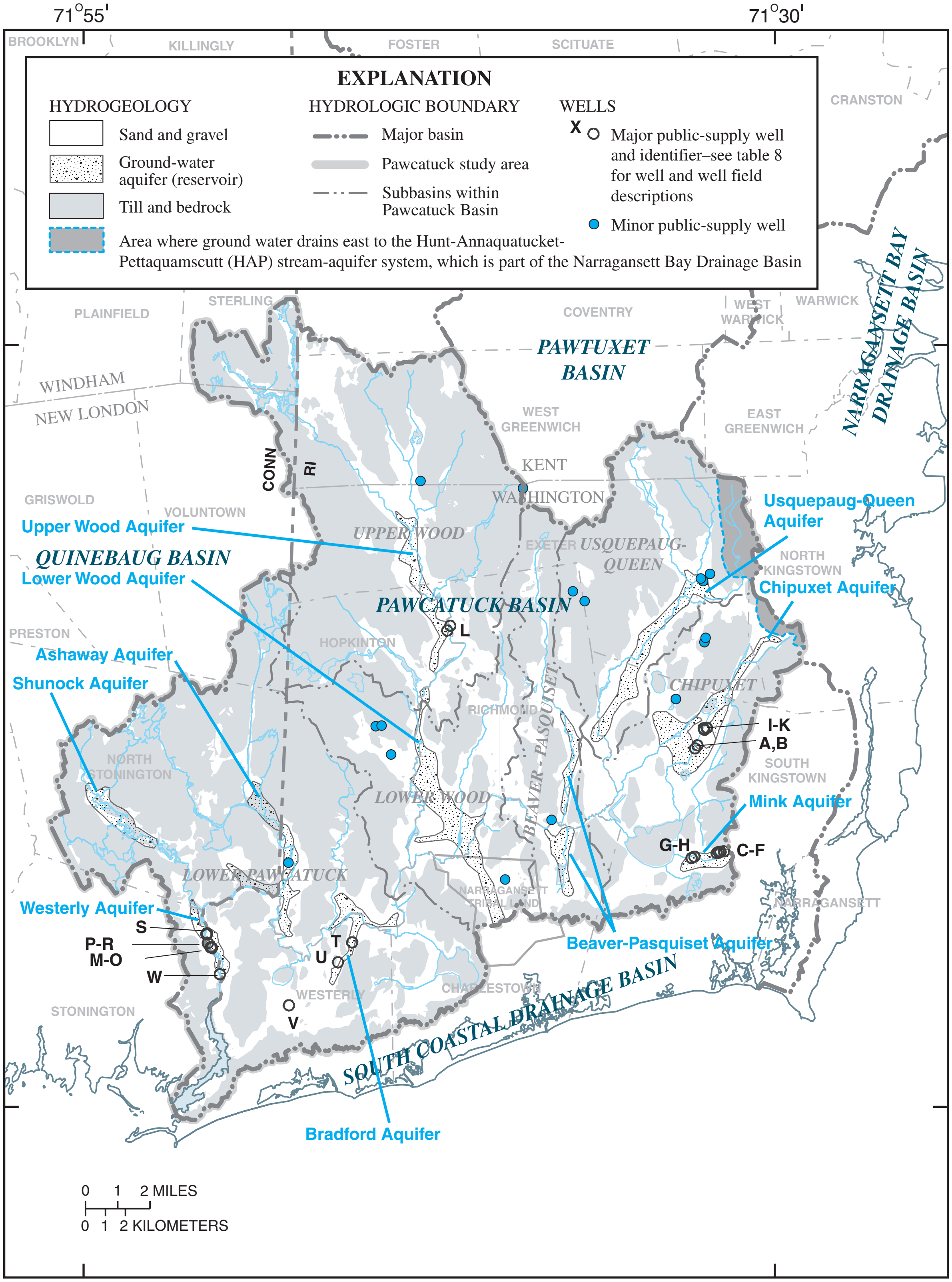
| Towns | Population | | Estimated 1995–99 population | | | |
|---|---|---|---|---|---|---|
| | 1990 | Estimated 1995–99 | Supply | | Disposal | |
| | | | Public | Self | Public | Self |
| Lower Pawcatuck Subbasin | | | | | | |
| Charlestown | 946 | 1,047 | 92 | 955 | 18 | 1,029 |
| Hopkinton | 3,473 | 3,924 | 337 | 3,587 | 125 | 3,799 |
| North Stonington, CT | 3,611 | 3,617 | 876 | 2,741 | 102 | 3,515 |
| Stonington, CT | 5,007 | 4,864 | 4,480 | 384 | 3,187 | 1,677 |
| Voluntown, CT | 194 | 207 | 2 | 205 | -- | 207 |
| Westerly | 18,891 | 20,022 | 19,371 | 651 | 12,862 | 7,160 |
| Subbasin total | 32,122 | 33,681 | 25,158 | 8,523 | 16,294 | 17,387 |
| Pawcatuck Basin | | | | | | |
| Basin total | 61,481 | 66,528 | 34,779 | 31,749 | 22,987 | 43,541 |

**Table 2.** Summary of climatological data pertinent to the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[Climatological data from monthly and annual summaries from the National Climate Data Center of the National Oceanic and Atmospheric Administration, 1971–2000. WSO, weather station observatory; °F, degrees Fahrenheit; in., inch]

| Climatological station | Period of record | Average temperature (°F) | | | | |
|---|---|---|---|---|---|---|
| | | June | July | August | September | Annual |
| Kingston, RI | 1971–2000 | 65.63 | 71.06 | 69.91 | 62.72 | 49.94 |
| | 1995–99 | 66.50 | 71.88 | 70.32 | 63.74 | 50.91 |
| Providence WSO Airport, Warwick, RI | 1971–2000 | 67.65 | 73.37 | 71.88 | 63.99 | 51.13 |
| | 1995–99 | 68.20 | 74.14 | 72.08 | 64.74 | 51.84 |

| Climatological station | Period of record | Average precipitation (in.) | | | | Annual total (in.) |
|---|---|---|---|---|---|---|
| | | June | July | August | September | |
| Kingston, RI | 1971–2000 | 3.936 | 3.308 | 4.400 | 4.163 | 51.79 |
| | 1995–99 | 4.106 | 2.728 | 4.356 | 4.474 | 53.11 |
| Providence WSO Airport, Warwick, RI | 1971–2000 | 3.382 | 3.169 | 3.904 | 3.704 | 46.46 |
| | 1995–99 | 3.414 | 1.978 | 3.190 | 4.014 | 43.91 |




Base from U.S. Geological Survey, Connecticut MAGIC, and Rhode Island GIS data sets
Rhode Island state plane, 5176 fipzone
Horizontal datum is NAD 83
Source map scale 1:300,000

**Figure 4.** Aquifers and selected withdrawal wells for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

**Table 3.** Town land area and land-use area by category in the subbasins of the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[Land-use areas were estimated by using the coverage from the Rhode Island Geographic Information System, 1995a. All towns are in Rhode Island unless otherwise noted. $mi^2$, square mile; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, not applicable]

| Towns | Land area ($mi^2$) | Land-use area by category ($mi^2$) | | |
|---|---|---|---|---|
| | | Commercial | Industrial | Agricultural |
| **Chipuxet Subbasin** | | | | |
| Charlestown | 1.040 | -- | -- | 0.046 |
| Exeter | 6.723 | 0.025 | 0.019 | .712 |
| North Kingstown | 3.057 | .001 | .014 | 1.051 |
| Richmond | 1.919 | .009 | -- | .709 |
| South Kingstown | 24.19 | .084 | .088 | 2.685 |
| Subbasin total | 36.93 | 0.119 | 0.121 | 5.203 |
| **Usquepaug–Queen Subbasin** | | | | |
| East Greenwich | 0.096 | -- | -- | -- |
| Exeter | 24.21 | 0.046 | 0.003 | 2.838 |
| North Kingstown | .318 | .016 | -- | .129 |
| Richmond | 4.503 | .006 | -- | .350 |
| South Kingstown | 3.599 | .002 | -- | .726 |
| West Greenwich | 3.374 | -- | .008 | .118 |
| Subbasin total | 36.10 | 0.070 | 0.011 | 4.161 |
| **Beaver–Pasquiset Subbasin** | | | | |
| Charlestown | 6.782 | 0.059 | 0.033 | 0.498 |
| Exeter | 2.334 | .043 | -- | .110 |
| Richmond | 13.16 | .013 | .016 | 1.400 |
| South Kingstown | .190 | -- | -- | -- |
| Subbasin total | 22.47 | 0.115 | 0.049 | 2.008 |
| **Upper Wood Subbasin** | | | | |
| Coventry | 0.872 | -- | -- | <0.001 |
| Exeter | 20.18 | 0.018 | 0.019 | .590 |
| Hopkinton | 13.45 | .033 | .022 | .938 |
| North Stonington, CT | .003 | -- | -- | -- |
| **Upper Wood Subbasin—*Continued*** | | | | |
| Richmond | 6.543 | 0.098 | 0.039 | 0.286 |
| Sterling, CT | 5.819 | -- | -- | .517 |
| Voluntown, CT | 3.365 | -- | .007 | .159 |
| West Greenwich | 22.75 | .040 | .018 | .965 |
| Subbasin total | 72.98 | 0.189 | 0.105 | 3.455 |
| **Lower Wood Subbasin** | | | | |
| Charlestown | 8.633 | 0.004 | 0.033 | 0.379 |
| Hopkinton | 13.14 | .011 | .011 | 1.022 |
| North Stonington, CT | .007 | -- | -- | -- |
| Richmond | 14.62 | .045 | .028 | 1.516 |
| Voluntown, CT | .017 | -- | -- | -- |
| Subbasin total | 36.42 | 0.060 | 0.072 | 2.917 |
| **Lower Pawcatuck Subbasin** | | | | |
| Charlestown | 8.692 | 0.007 | -- | 0.106 |
| Hopkinton | 17.55 | .117 | 0.032 | 1.832 |
| North Stonington, CT | 38.28 | -- | .530 | 4.322 |
| Stonington, CT | 5.125 | -- | .082 | .537 |
| Voluntown, CT | 4.504 | -- | .021 | .082 |
| Westerly | 23.30 | .542 | .114 | 1.360 |
| Subbasin total | 97.45 | 0.666 | 0.779 | 8.239 |
| **Pawcatuck Basin** | | | | |
| Basin total | 302.4 | 1.219 | 1.137 | 25.98 |

**Table 4.** Land-use area and percent land-use area by water-supply district for the subbasins in the Pawcatuck Basin study area and areas outside of the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[Land-use areas for the water-supply districts were estimated from coverages from the Rhode Island Geographic Information System, 1995a,b. $mi^2$, square mile; --, not applicable]

| Water supplier | Subbasin of well withdrawal | Land-use area by category in the Pawcatuck Basin ($mi^2$) | | | Land-use area by category outside of the Pawcatuck Basin ($mi^2$) | | |
|---|---|---|---|---|---|---|---|
| | | Commercial | Industrial | Agricultural | Commercial | Industrial | Agricultural |
| Kingston Water District | Chipuxet | 0.024 | 0.024 | 0.126 | 0.031 | 0.031 | 0.082 |
| United Water of Rhode Island | Chipuxet | .006 | -- | .333 | .441 | .067 | 1.095 |
| Richmond Water Supply | Upper Wood | .080 | .022 | .116 | -- | -- | -- |
| Westerly Water Division | Lower Pawcatuck | .536 | .097 | .841 | .154 | -- | .224 |

| Water supplier | Subbasin of well withdrawal | Percent land use in the Pawcatuck Basin | | | Percent land use outside of the Pawcatuck Basin | | |
|---|---|---|---|---|---|---|---|
| | | Commercial | Industrial | Agricultural | Commercial | Industrial | Agricultural |
| Kingston Water District | Chipuxet | 44 | 44 | 60 | 56 | 56 | 40 |
| United Water of Rhode Island | Chipuxet | 1 | -- | 23 | 99 | 100 | 77 |
| Richmond Water Supply | Upper Wood | 100 | 100 | 100 | -- | -- | -- |
| Westerly Water Division | Lower Pawcatuck | 78 | 100 | 79 | 22 | -- | 21 |

## Pawcatuck Subbasins

Because this study is based on the water availability in the sand and gravel aquifers, the USGS delineated the six subbasins of the Pawcatuck Basin based on the surface-water drainage areas contributing to the stratified sand and gravel deposits, and areas contributing to the upland till deposits (table 5). Barlow and Dickerman (2001) found that portions of the ground-water boundary differs from the surface-water boundary in the Chipuxet and Usquepaug–Queen subbasins. In these portions, the surface water drains to the Pawcatuck Basin, whereas the ground water drains to the Hunt–Annaquatucket–Pettaquamscutt stream-aquifer system. The differences in the land area and surficial deposits within the subbasins are presented in table 5. During a concurrent study in the Usquepaug–Queen subbasin, it was estimated that approximately 25 percent of the water within the subbasin drains to the Pawcatuck Basin during the wet season (P.J. Zarriello, oral commun., 2003). The ground-water flow boundary, therefore, was used for determining water availability for the summer in the Chipuxet and Usquepaug–Queen subbasins (table 5). Based on the surface-water drainage boundaries, approximately 37.1 percent of the Pawcatuck Basin is stratified sand and gravel deposits. Based on the ground-water boundaries, approximately 36.9 percent of the Pawcatuck Basin is stratified sand and gravel deposits (table 5). Among the sand and gravel deposits, the areas of saturated thickness that are greater 40 ft are referred to as ground-water reservoirs, or aquifers (table 5).

The USGS subbasin boundaries delineated for this study area differ from the cataloging units defined by the Watershed Boundary Dataset (WBD) delineations from the Natural Resources Conservation Service (NRCS). Naming conventions are another difference in the comparison between the Pawcatuck Basin study subbasins and the 10-digit and 12-digit cataloging units. Land area and naming convention comparisons are presented in table 6. The WBD spatial data primarily define the surface water features, and delineations are defined by using the criteria recommended by the Federal Geographic Data Committee (FGDC) in 2002. Additional information regarding the FGDC definitions, process, and current progress can be found at the FGDC Web site: ftp://ftp-fc.sc.egov/NCGC/products/watershed/hu-standards.doc/.

**Table 5.** Surface-water and ground-water drainage areas, the percentage of sand and gravel deposits and till deposits, and the ground-water reservoirs for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[Ground-water reservoir, or aquifer, is the area of stratified sand and gravel deposits with a saturated thickness of at least 40 feet. $mi^2$, square miles]

| Subbasin | Surface-water drainage areas | | | Ground-water drainage areas | | | Ground-water reservoir (aquifer) area ($mi^2$) |
|---|---|---|---|---|---|---|---|
| | Land area ($mi^2$) | Percent sand and gravel deposits | Percent till deposits | Land area ($mi^2$) | Percent sand and gravel deposits | Percent till deposits | |
| Chipuxet[1] | 36.93 | 59.4 | 40.6 | 35.98 | 58.7 | 41.3 | 4.256 |
| Usquepaug–Queen[2] | 36.10 | 34.2 | 65.8 | 33.07 | 33.5 | 66.5 | 2.612 |
| Beaver–Pasquiset | 22.47 | 44.4 | 55.6 | 22.47 | 44.4 | 55.6 | 1.630 |
| Upper Wood | 72.98 | 26.2 | 73.8 | 72.98 | 26.2 | 73.8 | 1.757 |
| Lower Wood | 36.42 | 47.5 | 52.5 | 36.42 | 47.5 | 52.5 | 4.075 |
| Lower Pawcatuck | 97.45 | 32.2 | 67.8 | 97.45 | 32.2 | 67.8 | 3.912 |
| Basin total | 302.4 | 37.1 | 62.9 | 302.4 | 36.9 | 63.1 | 18.24 |

[1]The difference between the surface-water and ground-water drainage areas in the Usquepaug–-Queen subbasin is 3.03 $mi^2$, where the surficial geology is 1.28 $mi^2$ sand and gravel deposits, and 1.75 $mi^2$ till deposits (P.M. Barlow, U.S. Geological Survey, oral commun., 2003).

[2]The difference between the surface-water and ground-water drainage areas in the Chipuxet subbasin is 0.95 $mi^2$, where the surficial geology is 0.80 $mi^2$ sand and gravel deposits, and 0.15 $mi^2$ till deposits (P.M. Barlow, U.S. Geological Survey, oral commun., 2003).

**Table 6.** Defined subbasins in the Pawcatuck Basin study area in Rhode Island compared to the 10-digit and 12-digit hydrologic units from the Natural Resources Conservation Service, Watershed Boundary Dataset in Rhode Island.

[The total land area in Rhode Island, 309.1 $mi^2$, for the Watershed Boundary Dataset for the Pawcatuck Basin 8-digit (01090005) hydrologic unit includes the South Coastal Drainage Basin, 56.40 $mi^2$, and Block Island, 7.752 $mi^2$, which are outside of the study area. $mi^2$, square mile]

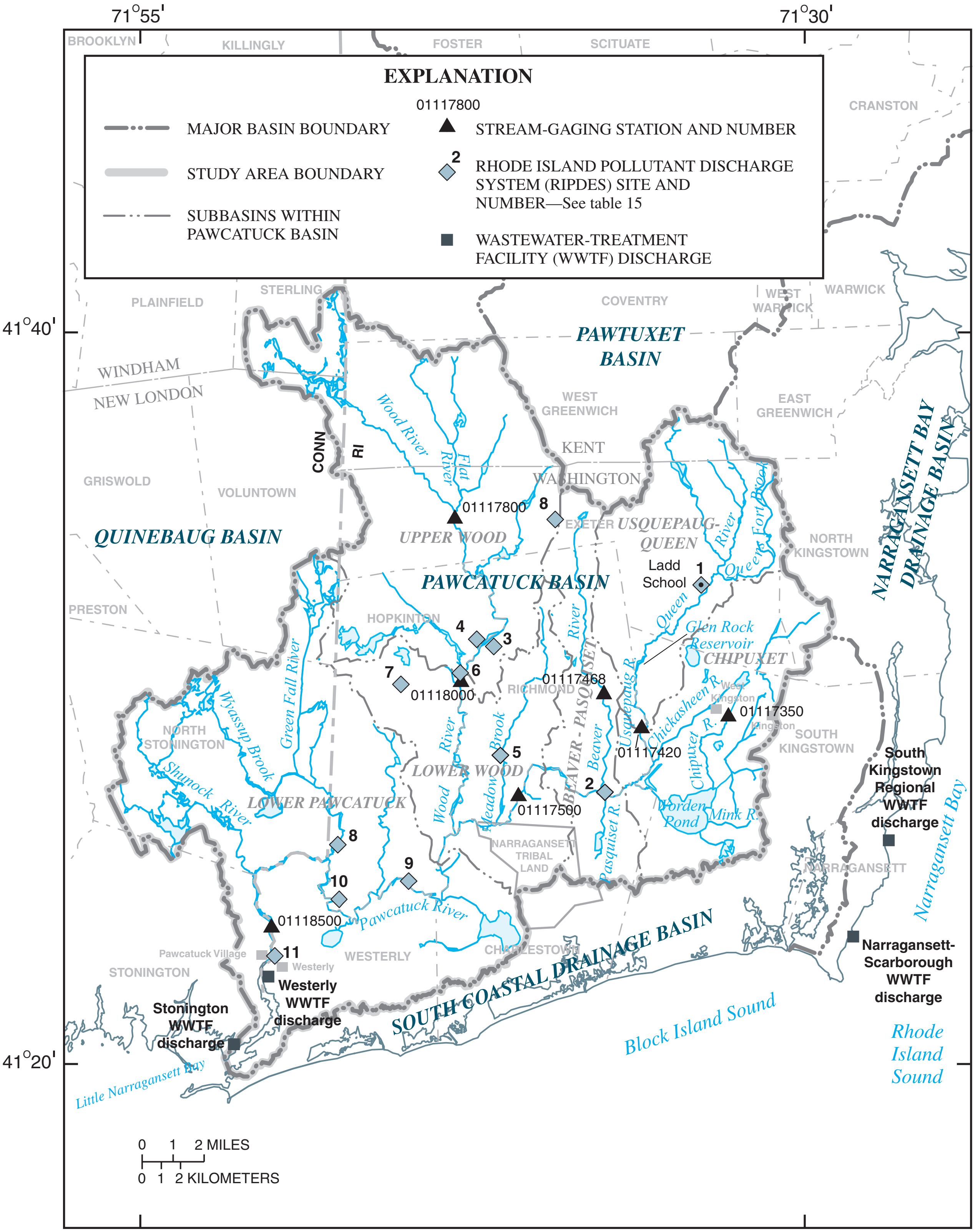
| Pawcatuck Basin study area in Rhode Island | | Watershed Boundary Dataset for Pawcatuck Basin in Rhode Island | | | | | |
|---|---|---|---|---|---|---|---|
| Subbasins | Drainage areas ($mi^2$) | 10-digit hydrologic unit | Number | Drainage areas ($mi^2$) | 12-digit hydrologic unit | Number | Drainage areas ($mi^2$) |
| Chipuxet | 36.93 | Wood River | 0109000501 | 79.70 | Upper Wood River | 010900050101 | 52.61 |
| Usquepaug–Queen | 36.10 | | | | Lower Wood River | 010900050102 | 27.09 |
| Beaver–Pasquiset | 22.47 | Upper Pawcatuck River | 0109000502 | 153.3 | Chipuxet River | 010900050201 | 25.79 |
| Upper Wood | 63.80 | | | | Queen River | 010900050202 | 36.63 |
| Lower Wood | 36.40 | | | | Beaver River | 010900050203 | 12.50 |
| Lower Pawcatuck | 49.50 | | | | Upper Pawcatuck River | 010900050204 | 21.61 |
| | | | | | Pawcatuck mainstem | 010900050205 | 56.82 |
| | | Lower Pawcatuck River | 0109000503 | 12.52 | Ashaway River | 010900050301 | 4.729 |
| | | | | | Lower Pawcatuck River | 010900050303 | 7.792 |
| Total Pawcatuck Basin study area in Rhode Island | 245.2 | Total 10-digit hydrologic unit | | 245.5 | Total 12-digit hydrologic unit | | 245.6 |

The Chipuxet subbasin (36.93 $mi^2$ drainage area) is in the eastern section of the Pawcatuck Basin in Rhode Island. Towns in the subbasin include Charlestown, Exeter, North Kingstown, Richmond, and South Kingstown (fig. 3). Land areas and land-use areas by category are summarized in tables 3 and 4. The Chipuxet River (considered the head of the Pawcatuck Basin) flows southwestward before it flows into the main stem of the Pawcatuck River. The Mink and Chipuxet Rivers flow into Worden Pond in South Kingstown, at which point the river is defined as the Pawcatuck River. The Mink and Chipuxet aquifers are ground-water sources for water suppliers in the subbasin (fig. 4); the Kingston Water District and University of Rhode Island (URI) withdraw from the Chipuxet aquifer, and United Water of Rhode Island (UWRI) withdraws from the Mink aquifer. The subbasin is 59 percent sand and gravel; however, included in this scenario is the 8.77 $mi^2$ (24 percent) of wetlands in the subbasin. There is one continuous stream-gaging station in the subbasin, the Chipuxet River at West Kingston, RI (station 01117350), with more than 27 years of surface-water data (fig. 5). The extent of sand and gravel deposits upstream of the stream-gaging station is 43 percent. In a small section in the northern area of the Chipuxet subbasin, the surface- and ground-water drainage boundaries do not overlap (fig. 3); the surface water drains to the Pawcatuck River to the southwest, and the ground water in approximately 0.95 $mi^2$ of the area in the subbasin discharges to the Hunt–Annaquatucket–Pettaquamscutt (HAP) aquifer system to the northeast (Barlow and Dickerman, 2001). The area of the ground-water drainage boundary discharging to the HAP is approximately 0.80 $mi^2$ sand and gravel deposits and 0.15 $mi^2$ till. This difference is addressed in this report for determining water availability during the summer because the amount of ground-water discharge available at the Chipuxet stream-gaging station was based on the amount of sand and gravel deposits and till deposits within the ground-water drainage boundary.

Because the Chipuxet subbasin is an area of concern to State and local municipalities, further analysis of water use and availability was completed in the area upstream of the Chipuxet stream-gaging station (fig. 5). In addition to assessing the defined subbasins, water withdrawals and water availability were calculated for the area upstream of the station. In particular, an assessment was made to determine the net availability in this specific area—the ratio of water withdrawals to the water available at the Chipuxet stream-gaging station for June, July, August, and September. This assessment will be discussed in more detail in other sections of this report.

The Usquepaug–Queen subbasin (36.10 $mi^2$ drainage area) is in the northeastern section of the Pawcatuck Basin in Rhode Island. The towns in the subbasin include East Greenwich, Exeter, North Kingstown, Richmond, South Kingstown, and West Greenwich (fig. 3). Land areas and land-use areas by category are summarized in tables 3 and 4. The Queen River flows south to Glen Rock Reservoir, and the Usquepaug River flows south from Glen Rock Reservoir to its confluence with the Pawcatuck River. The Usquepaug–Queen aquifer (fig. 4) is the primary source of ground water for the self-supplied water users within the subbasin. Approximately 34 percent of the subbasin is stratified sand and gravel deposits. There are two continuous stream-gaging stations in the subbasin (fig. 5), the Queen River at Liberty Road at Liberty, RI (station 01117370), which has 4 years of surface-water data (water years 1999–2002); and the Usquepaug River near Usquepaug, RI (station 01117420), which has more than 26 years of surface-water data. For this study, the Usquepaug stream-gaging station defines the subbasin confluence with the main stem of the Pawcatuck River. In a small section in the northern portion of the Usquepaug–Queen subbasin, the surface- and ground-water drainage boundaries do not overlap; the surface water drains to the Pawcatuck River to the southwest, and approximately 3.03 $mi^2$ of the ground water in the subbasin discharges to the HAP aquifer system to the east (Barlow and Dickerman, 2001), as illustrated in figure 3. The area of the ground-water drainage boundary that discharges to the HAP is approximately 1.28 $mi^2$ sand and gravel deposits and 1.75 $mi^2$ till. This difference is addressed in this report for determining water availability during the summer because the amount of ground-water discharge available at the Usquepaug River stream-gaging station was based on the amount of sand and gravel deposits within the ground-water drainage boundary.

The Beaver–Pasquiset subbasin (22.47 $mi^2$ drainage area) is in the eastern section of the Pawcatuck Basin in Rhode Island. The towns in the subbasin include Charlestown, Exeter, Richmond, and South Kingstown (fig. 3). Land areas and land-use areas by category are summarized in tables 3 and 4. The Beaver River flows south, and the Pasquiset River flows north into the Pawcatuck River, approximately in the center of the subbasin. The Beaver–Pasquiset aquifer (fig. 4) is the ground-water source for self-supplied water users in the subbasin. There is one continuous stream-gaging station (fig. 5), the Beaver River near Usquepaug, RI (station 01117468), which has more than 26 years of surface-water data. The surficial deposits are approximately 44 percent sand and gravel in the subbasin, and are approximately 26 percent sand and gravel in the area upstream of the stream-gaging station 01117468.




Base from U.S. Geological Survey, Connecticut MAGIC, and Rhode Island GIS data sets
Rhode Island state plane, 5176 fipzone
Horizontal datum is NAD 83
Source map scale 1:300,000

**Figure 5.** Stream-gaging stations and wastewater-treatment facilities associated with the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

The Upper Wood subbasin (72.98 $mi^2$ drainage area) is in the northwestern section of the Pawcatuck Basin in Rhode Island (63.79 $mi^2$ drainage area) and Connecticut (9.187 $mi^2$ drainage area). The Rhode Island towns in the subbasin include Coventry, Exeter, Hopkinton, Richmond, and West Greenwich (fig. 3). Connecticut towns include North Stonington, Sterling, and Voluntown. Land areas and land-use areas by category are summarized in tables 3 and 4. The Upper Wood River flows southeasterly from Connecticut into Rhode Island. The Upper Wood aquifer (fig. 4) is the source for some self-supplied water users and the Richmond Water Supply District. The subbasin is in Rhode Island (88 percent) and Connecticut (12 percent), and the surficial deposits are approximately 26 percent sand and gravel. There are two continuous stream-gaging stations in the subbasin (fig. 5), Wood River at Arcadia, RI (station 01117800), and Wood River at Hope Valley, RI (station 01118000), with more than 35 and 59 years of data, respectively. The surficial deposits in the area upstream of the Arcadia stream-gaging station are approximately 28 percent sand and gravel. The surficial deposits in the area upstream of the Hope Valley stream-gaging station are approximately 26 percent sand and gravel.

The Lower Wood subbasin (36.42 $mi^2$ drainage area) is in the western section of the Pawcatuck Basin in Rhode Island (36.40 $mi^2$ drainage area) and Connecticut (0.024 $mi^2$ drainage area). The Rhode Island towns in the subbasin are Charlestown, Hopkinton, and Richmond, and the Connecticut towns in the subbasin are North Stonington and Voluntown (fig. 3). Land areas and land-use areas by category are summarized in tables 3 and 4. The stream-gaging station at Hope Valley defines the split between the Upper and Lower Wood subbasins (fig. 4). The Lower Wood River continues to flow south, but encompasses Meadow Brook from the east before the confluence with the Pawcatuck River in Alton, RI. The water withdrawals in the Lower Wood aquifer (fig. 4) are from self-supplied entities. The surficial deposits in the subbasin are 48 percent sand and gravel. The area draining to the Pawcatuck River at Wood River Junction (station 01117500) is 100 $mi^2$; this station is the only continuous stream-gaging station in the subbasin (fig. 5). More than 60 years of surface-water data are available for the station. Approximately 47 percent of the drainage area at the stream-gaging station is sand and gravel deposits.

The Lower Pawcatuck subbasin (97.45 $mi^2$ drainage area) is in the southwestern section of the Pawcatuck Basin in Rhode Island (49.54 $mi^2$ drainage area) and Connecticut (47.91 $mi^2$ drainage area). The subbasin includes the towns of Charlestown, Hopkinton, and Westerly in Rhode Island, and North Stonington, Stonington, and Voluntown in Connecticut (fig. 3). Land areas and land-use areas by category are summarized in tables 3 and 4. The Green Fall River, Wyassup Brook, and Shunock River flow southeasterly into the Pawcatuck River, which flows southwesterly into Long Island Sound. The Ashaway, Shunock, Bradford, and Westerly aquifers (fig. 4) are the defined ground-water sources in the Lower Pawcatuck subbasin. The Lower Pawcatuck subbasin is approximately 32 percent sand and gravel deposits. The continuous stream-gaging station in the subbasin (fig. 5), Pawcatuck River at Westerly, RI (station 01118500), has more than 62 years of surface-water data. The surficial deposits are approximately 37 percent sand and gravel for the area upstream of the Westerly stream-gaging station.

## Minor Civil Divisions

The U.S. Census Bureau classifies towns and cities into minor civil divisions (MCDs). The 14 MCDs in the study area include Charlestown, Coventry, East Greenwich, Exeter, Hopkinton, North Kingstown, Richmond, South Kingstown, West Greenwich, and Westerly in Rhode Island, and North Stonington, Sterling, Stonington, and Voluntown in Connecticut. The study area also includes part of the Narragansett Tribal Land in the southeastern section of Charlestown. The town of Narragansett is in the Narragansett Bay Drainage Basin, but is included in sections of this report to account for interbasin transfers. Polygons within the towns were assigned population densities in the GIS coverages by using Census Bureau TIGER data available through the Rhode Island Geographic Information System (RIGIS) and the Connecticut Map and Geographic Information Center (MAGIC). These 1990 population coverages were merged with the USGS basin and subbasin coverage to determine the population in the Pawcatuck Basin, and in the subbasins (table 1). Also, the town land area by basin and subbasin was determined by overlaying town boundaries and basin-boundary coverages. The ratio of the 1990 to 1995 through 1999 populations for towns by subbasins is the increase (or decrease) of the town population. To estimate the 1995 through 1999 town populations on public- and self-water supplies and public- and self-wastewater disposals, the population ratio was multiplied by the 1990 population on private wells and the 1990 population on public-wastewater collection (table 1) that were available through RIGIS and the Connecticut MAGIC. Public-water suppliers are defined by the U.S. Environmental Protection Agency (USEPA) as suppliers serving more than 25 people or having 15 service connections year-round. For this report, public suppliers were categorized into major public suppliers that have a system of distribution, and minor suppliers that have closed systems.

The town of Charlestown is in south central Rhode Island (fig. 3). The total land area is 37.63 $mi^2$, of which 25.1 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 7,062, and the estimated town population in the basin for the study period was 4,218 (table 7). Charlestown also includes the Narragansett Tribal Land, which comprises 1,400 acres in the southeastern section of the town (Narragansett Indian Tribe, 2002). Charlestown has no major public-water supply or wastewater-collection facilities, and only one minor water supplier that serves a small population.

**Table 7.** Summary of total land area, land area in the Pawcatuck Basin, total 1990 populations, total estimated 1995–99 populations, estimated 1995–99 populations in the Pawcatuck Basin, and land-use area by category in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[All towns are in Rhode Island unless otherwise noted. **Total populations: Rhode Island 1990—**From Rhode Island Geographic Information System (1991). **Estimated 1995–99—**From the Rhode Island Economic Development Corporation (2000); **Connecticut 1990—**From the University of Connecticut Center for Geographic Information and Analysis (2000). **Estimated 1995–99—**From the Connecticut Department of Health (1995, 1996, 1997, 1998, 1999). **Land-use area by category: Rhode Island—**Estimated by using the coverage from the Rhode Island Geographic Information System (1995a); **Connecticut—**Estimated from the Map and Geographic Information Center (1990a, 1990b, 1990c, 1990d). $mi^2$, square mile; --, not applicable]

| Towns | Total land area ($mi^2$) | Land area in the Pawcatuck Basin ($mi^2$) | Total populations | | Estimated 1995–99 population in the Pawcatuck Basin | Total land-use area by category ($mi^2$) | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1990 | Estimated 1995–99 | | Commercial | Industrial | Agricultural |
| Charlestown | 37.63 | 25.53 | 6,381 | 7,062 | 4,218 | 0.302 | 0.066 | 1.439 |
| Coventry | 62.45 | .873 | 31,081 | 32,523 | 67 | .627 | .355 | 2.392 |
| East Greenwich | 16.25 | .095 | 11,807 | 12,120 | 38 | .349 | .195 | .924 |
| Exeter | 58.39 | 53.41 | 5,472 | 5,932 | 5,413 | .140 | .042 | 4.451 |
| Hopkinton | 44.10 | 44.10 | 6,871 | 7,763 | 7,763 | .162 | .065 | 3.791 |
| North Kingstown | 43.42 | 3.374 | 23,774 | 25,906 | 873 | .788 | 1.676 | 3.133 |
| North Stonington, CT | 54.94 | 38.29 | 4,884 | 4,892 | 3,617 | .536 | .536 | 5.105 |
| Richmond | 40.74 | 40.74 | 5,350 | 6,631 | 6,631 | .172 | .082 | 4.262 |
| South Kingstown | 60.85 | 27.98 | 24,632 | 26,401 | 10,682 | .490 | .155 | 7.666 |
| Sterling, CT | 27.31 | 5.819 | 2,357 | 2,755 | 444 | -- | -- | 2.229 |
| Stonington, CT | 38.70 | 5.125 | 16,919 | 16,435 | 4,864 | 1.426 | 1.426 | 3.110 |
| Voluntown, CT | 39.78 | 7.886 | 2,113 | 2,252 | 410 | .092 | .092 | 1.778 |
| West Greenwich | 51.22 | 26.13 | 3,501 | 3,956 | 1,486 | .227 | .064 | 1.865 |
| Westerly | 29.51 | 22.91 | 21,603 | 22,896 | 20,022 | .696 | .114 | 1.584 |

The town of Coventry is in central Rhode Island (fig. 3). The total land area is 62.45 $mi^2$, of which 0.873 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 32,523, and the estimated town population in the basin for the study period was 67 (table 7). Although the Kent County Water Authority supplies water to a section of Coventry in the Pawtuxet Basin, the portion of the town in the Pawcatuck Basin is self-supplied. Likewise, the wastewater-collection area for the town of Coventry is outside of the Pawcatuck Basin.

The town of East Greenwich is in central Rhode Island (fig. 3). The total land area is 16.25 $mi^2$, of which 0.095 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 12,120, and the estimated town population in the basin for the study period was 38 (table 7). The Kent County Water Authority supplies water to all of East Greenwich, and the East Greenwich Wastewater-Treatment Facility (WWTF) collects wastewater for the community.

The town of Exeter is in south central Rhode Island (fig. 3). The total land area is 58.39 $mi^2$, of which 53.41 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 5,932, and the estimated town population in the basin for the study period was 5,413 (table 7). There are no major public water suppliers in Exeter. The Ladd School, however, a minor public-water supplier and wastewater-treatment facility, was in operation for 5 months (from January through May of 1995) during the study period. The facility is currently (2004) owned by the Rhode Island Economic Development Corporation (RIEDC) and is undeveloped. Three minor public-water suppliers serve small populations in the basin.

The town of Hopkinton is in southwestern Rhode Island (fig. 3). The total land area is 44.10 $mi^2$, all of which is located in the Pawcatuck Basin (table 7). The estimated population for the study period was 7,763 (tables 7). Hopkinton has no public water-supply system, although a small portion of the town is served by the Richmond Water Supply District, and four minor public-water suppliers serve small populations. Likewise, the town has no local wastewater collection.

The town of Narragansett is in south central Rhode Island (fig. 3). The town is not located in the Pawcatuck Basin, but is included in this study to account for interbasin transfers. The estimated total population for the study period was 15,777. The Narragansett Water Department supplies the town through wholesale and retail water purchases from UWRI, which withdraws its water from the Pawcatuck Basin. Wastewater is collected from the town by the Narragansett WWTF, in the locality of Scarborough, and by the South Kingstown Regional WWTF.

The town of North Kingstown is in central Rhode Island (fig. 3). The total land area is 43.42 $mi^2$, of which 3.374 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 25,906, and the estimated town population in the basin for the study period was 873 (table 7). The North Kingstown Water District serves approximately 94 percent of the town. There is no public wastewater collection in North Kingstown. A private wastewater-treatment facility serves the Quonset Point establishment, formerly a U.S. Navy Air Station, which is currently (2004) owned and operated by the RIEDC.

The town of Richmond is in southwestern Rhode Island (fig. 3). The total land area is 40.74 $mi^2$ and it is all within the Pawcatuck Basin (table 7). The estimated total town population for the study period was 6,631 (table 7). The Richmond Water Supply District serves populations of the town in the Upper Wood subbasin of the Pawcatuck Basin, and serves a small section of the town of Hopkinton. Richmond has no public wastewater collection. One minor water supplier serves a small population in the basin.

The town of South Kingstown is in south-central Rhode Island (fig. 3). The total land area is 60.85 $mi^2$, of which 27.98 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 26,401, and the estimated town population in the basin for the study period was 10,682 (table 7).

Four major water suppliers withdraw and serve the town of South Kingstown: URI, Kingston Water District, UWRI, and South Kingstown Water Department. Located in the northwestern portion of South Kingstown, all of URI at Kingston is in the Pawcatuck Basin, and supplies the residential community and campus facilities. Approximately 10,000 to 13,000 people are supplied at URI from September to May, and 3,000 to 7,000 are supplied from June through August. The Kingston Water District supplies the rest of the locality in the Pawcatuck Basin, as well as areas outside of the basin. Northeastern sections of South Kingstown (Wakefield and Peace Dale) are also supplied by a private water utility, UWRI, which withdraws water from the Pawcatuck Basin. In addition, UWRI distributes retail water to the town and sells water wholesale to the South Kingstown Water Department and to the Narragansett Water Department. The total average population of the towns served by UWRI during the study period was 18,000. Along the coast, in the southern part of the town, the South Kingstown Water Department withdraws and distributes water outside of the Pawcatuck Basin. These withdrawals are not included in the remainder of this report; however, the Narragansett Water Department purchases from UWRI are included as exports from the Pawcatuck Basin. The South Kingstown Regional WWTF serves the town and some sections of Narragansett. Wastewater collected within the Kingston Water District and the URI service area is exported to the South Kingstown Regional WWTF located outside of the study area. One minor water supplier serves a small population in the basin.

The town of West Greenwich is in central Rhode Island (fig. 3). The total land area is 51.22 $mi^2$, of which 26.13 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 3,956, and the estimated town population in the basin for the study period was 1,486 (table 7). The Kent County Water Authority serves part of the town of West Greenwich that is not in the basin; therefore, the Kent County Water Authority service area is not included in this report. Likewise, a small area outside of the basin is served by the West Warwick Regional WWTF. One minor water supplier serves a small population in the basin.

The town of Westerly is in southwestern Rhode Island (fig. 3). The total land area is 29.51 $mi^2$, of which 22.91 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 22,896, and the estimated town population in the basin for the study period was 20,022 for the study period (table 7). The Westerly Water Department serves the town and the village of Pawcatuck in Stonington, CT. The Westerly wastewater facility serves only the town.

The town of North Stonington is in southeastern Connecticut (fig. 3). The total land area is 54.94 $mi^2$, of which 38.29 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 4,892, and the estimated town population in the basin for the study period was 3,617 (table 7). There are no major water-supply or wastewater-collection systems in the portion of the town in the basin.

The town of Sterling is in eastern Connecticut (fig. 3). The total land area is 27.31 $mi^2$, of which 5.819 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 2,755, and the estimated town population in the basin for the study period was 444 (table 7). There are no major water-supply or wastewater-collection systems in the part of the town in the basin.

The town of Stonington is in southeastern Connecticut (fig. 3). The total land area is 38.70 $mi^2$, of which 5.125 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 16,435, and the estimated town population in the basin for the study period was 4,864 (table 7). The Stonington village of Pawcatuck is in the basin. As previously mentioned, the town of Westerly Water Department serves the village of Pawcatuck. The Southern Connecticut Water Authority also supplies water to Stonington in areas outside of the basin. The Stonington Water Pollution Control Authority has three collection and treatment facilities in the town: Stonington-Borough, Stonington-Mystic, and Stonington-Pawcatuck. The Stonington-Pawcatuck facility is the only facility in the town whose service area and discharge is in the Pawcatuck Basin.

The town of Voluntown is in eastern Connecticut (fig. 3). The total land area is 39.78 $mi^2$, of which 7.886 $mi^2$ is in the Pawcatuck Basin (table 7). The estimated total town population for the study period was 2,252, and the estimated town population in the basin for the study period was 410 (table 7). There are no major public water supplies or WWTFs in Voluntown. The majority of the town land area, 70 percent, is the Pachaug State Forest.

# Water Use

Water-use data for the Pawcatuck Basin and subbasins were organized by using the New England Water-Use Data System (NEWUDS). Components of water use include water withdrawals, public-supply systems and distributions, non-account use, water use by category, consumptive water use, wastewater-system collections, and return flow (fig. 2). During the study period, data were categorized as either self- or public-supplied withdrawals from ground water. Conveyance losses are an example of non-account water use (which is unmetered) in public-supply systems, and include leaks, system flushing, and fire-hydrant uses within the systems. The non-account water use for a public-supply system is the total distribution minus the public-supply distributions for the water-use categories in the system. Water-use categories used in this report are domestic, commercial, industrial, and agricultural for public- and self-supplied users. The public-water supply and self-supplied domestic, industrial, and commercial withdrawals were from ground water. Consumptive water use is water removed from the environment through uses by humans, livestock, production, or evapotranspiration. Wastewater from local and regional public-wastewater systems is returned to a surface-water body. Return flow to ground water or surface water includes site-specific discharges, permitted dischargers, and aggregate dischargers, which are self-disposed within the town, basin, and subbasins. Water withdrawals, water use, consumptive use, and return flow were calculated for each subbasin by town for the calendar years during the study period.

## New England Water-Use Data System

The data entered into NEWUDS consist of site-specific and aggregate water withdrawals, uses, and discharges in the Pawcatuck Basin and its subbasins. When available, monthly, quarterly, and yearly metered (or reported) data were entered from original source and converted to common units (Mgal/d) for comparison of the data. Unmetered water withdrawals, uses, and discharges were calculated by methods used to estimate water use by category (domestic, industrial, commercial, and agricultural). The database was used as a tool to track the water withdrawn from the Pawcatuck Basin and subbasins. The database was queried to obtain the average water use for the study period, and the results are in the tables of this report. For quality-assurance purposes, NEWUDS allows the data compiler to indicate the original data source, rate units, and method of rate determined within the database. Documentation describing database development and how to use the database are presented in the reports by Tessler (2002) and Horn (2003), respectively.

## Public-Water Supply and Interbasin Transfers

Public-water suppliers are defined as suppliers serving more than 25 people or having 15 service connections year-round. For this report, public suppliers were categorized into major public suppliers (table 8) that have a system of distribution, and minor suppliers that have closed systems. Five major public-water suppliers serve the Pawcatuck Basin: Kingston Water District, UWRI, URI, Richmond Water Supply District, and the Westerly Water Department, which supply the domestic, commercial, industrial, and agricultural sectors. Thirteen minor water suppliers serve small public populations, such as nursing homes, condominium associations, and mobile home parks (table 9). All estimated public-water supply withdrawals, and self-supplied withdrawals, by town and subbasin, are listed in table 10. The total water withdrawals, use, and return flow from public and self supplies by town and subbasin are summarized in figures 6, 7, and 8.

The Kingston Water District supplies the domestic, industrial, commercial, and agricultural water users in the locality of Kingston. The average withdrawals for the study period were 0.444 Mgal/d from the Chipuxet aquifer in the Chipuxet subbasin, water use in the subbasin was approximately 0.362 Mgal/d, and the interbasin transfers (export) to the South Coastal Drainage Basin and West Narragansett Bay Drainage Basin were approximately 0.082 Mgal/d. The Kingston Water District accounts for 10 percent of the total withdrawals in the Chipuxet subbasin and 4 percent of the total withdrawals in the Pawcatuck Basin. The water withdrawals and distributions are summarized in figure 9 and table 8.

The UWRI system includes the Tuckertown (four wells) and Howland (two wells) well fields that are in the Chipuxet subbasin. This supply system withdrew an average of 2.603 Mgal/d during the study period from the Mink aquifer. UWRI withdrew 62 percent of the total withdrawals in the Chipuxet subbasin and 23 percent of the total withdrawals in the basin. The withdrawals and distributions are summarized in figures 7 and 10 and table 8 for the UWRI system.

URI supplies the student residents and other school uses from the Chipuxet subbasin. During the study period, URI withdrew approximately 0.440 Mgal/d from the Chipuxet aquifer. URI withdrew 10 percent of the total withdrawals in the Chipuxet subbasin and 4 percent of the total withdrawals in the Pawcatuck Basin. The withdrawals, use, and exports are summarized in figure 11 and table 8 for the URI water supply.

The major water supplier that withdrew the least amount of water in the basin was the Richmond Water Supply. Richmond Water Supply withdrew an average of 0.045 Mgal/d during the study period from the Upper Wood aquifer in the Upper Wood subbasin. The Richmond Water Supply withdrew 6 percent of the total withdrawals in the Upper Wood subbasin and 0.4 percent of the total withdrawals in the basin. The withdrawals and uses are summarized in figure 12 and table 8 for the water-supply system.

The largest major water supplier in the Pawcatuck Basin is the Westerly Water Department, in the Lower Pawcatuck subbasin. This supplier withdrew an average of 3.236 Mgal/d during the study period. The Westerly Water Department withdrew 75 percent of the total withdrawals in the Lower Pawcatuck subbasin and 29 percent of the total withdrawals in the Pawcatuck Basin. The water withdrawals and use are summarized in figure 13 and table 8 for the Westerly Water Department.

Thirteen minor water suppliers serve the Pawcatuck Basin (table 9). Limited data are available on these water withdrawals; therefore, water use was estimated by applying the water-use coefficient for public-water supply (67 gal/d/person in Rhode Island, and 70 gal/d/person in Connecticut) determined by Korzendorfer and Horn (1995). The total estimated water withdrawals in the basin for minor suppliers was 0.099 Mgal/d. Estimated water withdrawals for the subbasins ranged from 0.005 Mgal/d (Beaver–Pasquiset subbasin) to 0.025 Mgal/d (Lower Wood subbasin). Estimated water withdrawals for the individual minor suppliers ranged from 0.004 Mgal/d to 0.013 Mgal/d.

Three systems transfer public-supply water out of the Pawcatuck Basin. The Kingston Water District exports about 0.082 Mgal/d to the South Coastal and West Narragansett Bay Drainage Basins from the Chipuxet subbasin in the Pawcatuck Basin. The UWRI system distributes water within the South Coastal Drainage Basin, the West Narragansett Bay Drainage Basin, and the Pawcatuck Basin. Wholesale distributions from the UWRI system are exported to the South Kingstown and Narragansett Water Departments, whose service areas are in the South Coastal Drainage Basin and West Narragansett Bay Drainage Basin. The 1995 through 1999 average amount of wholesale water purchased by South Kingstown from UWRI was 0.040 Mgal/d. The 1995 through 1999 average amount of wholesale water purchased by the Narragansett Water Department from UWRI was 0.633 Mgal/d. The total exports from these two wholesale purchases was 0.673 Mgal/d from the Chipuxet subbasin of the Pawcatuck Basin. Parts of the Westerly Water Department retail service area are in the South Coastal Drainage Basin, and approximately 0.288 Mgal/d were exported out of the Lower Pawcatuck subbasin of the Pawcatuck Basin.

**Table 8.** Major public-water suppliers by subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[Usquepaug–Queen, Beaver–Pasquiset, and Lower Wood subbasins have no major public-water suppliers. **Reference letter:** Identifer used in figure 4. All towns/cities assumed to be in Rhode Island unless otherwise noted. **Aquifer type:** SG, sand and gravel. Mgal/d, million gallons per day; --, not applicable]

| Major public-water supplier | Reference letter | Town (locality) | Well field and well description (Mgal/d) | Aquifer | | Water withdrawals 1995–99 (Mgal/d) |
|---|---|---|---|---|---|---|
| | | | | Type | Name | |
| **Chipuxet Subbasin** | | | | | | |
| Kingston Water Department | A | South Kingstown (Kingston) | Well 1 | SG | Chipuxet | 0.137 |
| | B | South Kingstown (Kingston) | Well 2 | SG | Chipuxet | .307 |
| Total | | | | | | 0.444 |
| United Water of Rhode Island | C | South Kingstown (Wakefield) | Tuckertown well field: well 1 | SG | Mink | .012 |
| | D | South Kingstown (Wakefield) | Tuckertown well field: well 2 | SG | Mink | .297 |
| | E | South Kingstown (Wakefield) | Tuckertown well field: well 3 | SG | Mink | .010 |
| | F | South Kingstown (Wakefield) | Tuckertown well field: well 4 | SG | Mink | .398 |
| | G | South Kingstown (Wakefield) | Howland well field: well 5 | SG | Mink | .839 |
| | H | South Kingstown (Wakefield) | Howland well field: well 6 | SG | Mink | 1.047 |
| Total | | | | | | 2.603 |
| University of Rhode Island | I, J, K | South Kingstown (Kingston) | Well field: well 2, well 3, and well 4 | SG | Chipuxet | .440 |
| Subbasin Total | | | | | | 3.487 |
| **Upper Wood Subbasin** | | | | | | |
| Richmond Water Supply | L | Richmond | Well 1 | SG | Upper Wood | 0.045 |
| | | | Well 2 (backup only) | SG | Upper Wood | -- |
| Subbasin total | | | | | | 0.045 |
| **Lower Pawcatuck Subbasin** | | | | | | |
| Westerly Water Department | M, N, O | Westerly | Well field 1: well 1A, well 1B, well 1C | SG | Westerly | 0.845 |
| | P, Q, R | Westerly | Well field 2: well 2A, well 2B, well 2C | SG | Westerly | 1.081 |
| | S | Westerly | Well 3 | SG | Westerly | .432 |
| | T | Westerly | Bradford Well II | SG | Bradford | .270 |
| | U | Westerly | Bradford Well III | SG | Bradford | .281 |
| | V | Westerly | Crandall well | SG | Bradford | .327 |
| | W | Stonington, CT (Pawcatuck) | Noyes Avenue well (backup only) | SG | Westerly | -- |
| Subbasin total | | | | | | 3.236 |
| **Pawcatuck Basin** | | | | | | |
| Basin total | | | | | | 6.768 |

**Table 9.** Minor public-water suppliers by subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[Coefficient used for minor-supplier population is 67 gal/d/person. BD, bedrock well; DG, dug well; SG, sand and gravel well; gal/d/person, gallons per day per person; Mgal/d, million gallons per day]

| Minor public-water supplier | Town | Type of well(s) | Estimated 1995–99 | |
|---|---|---|---|---|
| | | | Population | Water withdrawals and use (Mgal/d) |
| Chipuxet Subbasin | | | | |
| Allen Health Center | South Kingstown | SG and BD | 175 | 0.012 |
| Split Rock | Exeter | BD and DG | 140 | .009 |
| Usquepaug–Queen Subbasin | | | | |
| Hillesdale Mobile Home Park | Richmond | BD | 200 | 0.013 |
| Ladd School[1] | Exeter | SG | 60 | .004 |
| Shady Acres Rest Home | Exeter | BD | 77 | .005 |
| Beaver–Pasquiset Subbasin | | | | |
| Shannock Water Association | Richmond | BD | 75 | 0.005 |
| Upper Wood Subbasin | | | | |
| Camp E-Hun-Tee | West Greenwich | BD | 65 | 0.004 |
| Mobile Village Park | Exeter | BD | 150 | .010 |
| Lower Wood Subbasin | | | | |
| Canonchet Cliffs I | Hopkinton | BD | 63 | 0.004 |
| Canonchet Cliffs II | Hopkinton | BD | 59 | .004 |
| Indian Cedar Mobile Home Park | Charlestown | BD | 140 | .009 |
| Lindhbrook Greene Condo | Hopkinton | SG | 120 | .008 |
| Lower Pawcatuck Subbasin | | | | |
| Bethal Village Water Association | Hopkinton | BD | 180 | 0.012 |
| Pawcatuck Basin | | | | |
| Total | | | 1,504 | 0.099 |

[1]Ladd School facility did not withdraw after May 1995.

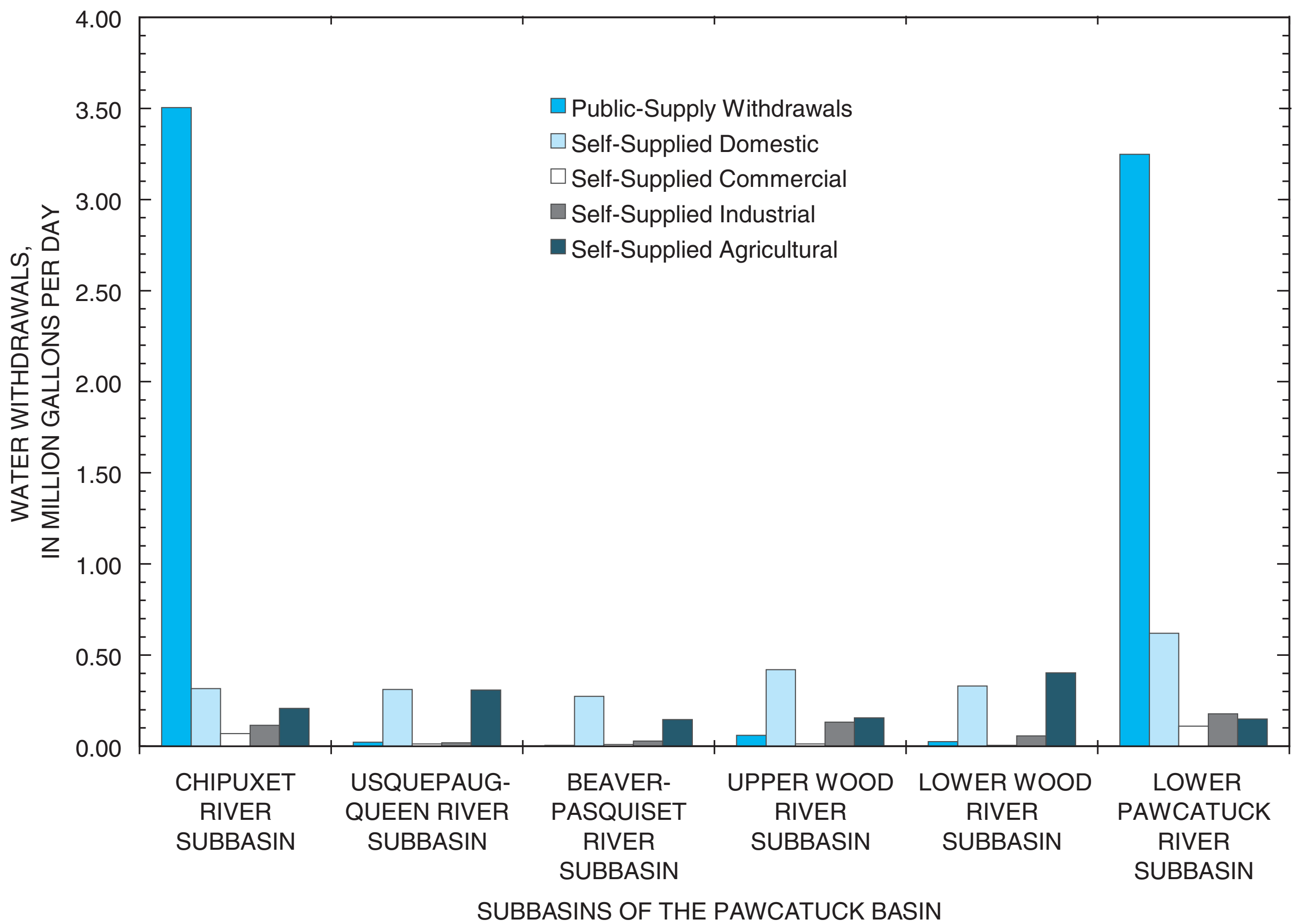



**Figure 6.** Public-supply withdrawals, and self-supplied domestic, commercial, industrial, and agricultural withdrawals for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

**Table 10.** Ground-water and surface-water withdrawals by town and subbasin in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[Public-supply, domestic, commercial, and industrial water withdrawals are from ground water (wells). For agriculture, irrigation-water withdrawals are assumed to be 81 percent from surface water (ponds and rivers), and 13 percent from ground water (wells). Livestock water withdrawals are assumed to be 9 percent from surface water and 82 percent from ground water. The remaining 6 percent for irrigation and 9 percent for livestock are estimated to be on public supply. All towns are in Rhode Island unless otherwise noted. Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, not applicable]

| Towns | Public-supply withdrawals (Mgal/d) | Self-supply withdrawals (Mgal/d) | | | | Total (Mgal/d) |
|---|---|---|---|---|---|---|
| | | Domestic | Commercial | Industrial | Agricultural | |
| **Chipuxet Subbasin** | | | | | | |
| Charlestown | -- | 0.016 | -- | -- | 0.002 | 0.018 |
| Exeter | 0.009 | .056 | 0.003 | 0.011 | .033 | .112 |
| North Kingstown | -- | .009 | <.001 | .002 | .041 | .052 |
| Richmond | -- | .022 | .001 | -- | .027 | .050 |
| South Kingstown | 3.496 | .213 | .065 | .102 | .104 | 3.980 |
| Subbasin total | 3.505 | 0.316 | 0.069 | 0.115 | 0.207 | 4.212 |
| **Usquepaug–Queen Subbasin** | | | | | | |
| East Greenwich | -- | 0.001 | -- | -- | <0.001 | 0.001 |
| Exeter | 0.009 | .209 | 0.006 | 0.002 | .190 | .416 |
| North Kingstown | -- | .001 | .004 | -- | .005 | .010 |
| Richmond | .013 | .052 | .001 | -- | .014 | .080 |
| South Kingstown | -- | .032 | .002 | -- | .098 | .132 |
| West Greenwich | -- | .017 | -- | .017 | .001 | .035 |
| Subbasin total | 0.022 | 0.312 | 0.013 | 0.019 | 0.308 | 0.674 |
| **Beaver–Pasquiset Subbasin** | | | | | | |
| Charlestown | -- | 0.099 | 0.003 | 0.002 | 0.019 | 0.123 |
| Exeter | -- | .020 | .005 | -- | .004 | .029 |
| Richmond | 0.005 | .153 | .001 | .027 | .124 | .310 |
| South Kingstown | -- | .001 | -- | -- | -- | .001 |
| Subbasin total | 0.005 | 0.273 | 0.009 | 0.029 | 0.147 | 0.463 |
| **Upper Wood Subbasin** | | | | | | |
| Coventry | -- | 0.005 | -- | -- | <0.001 | 0.005 |
| Exeter | 0.010 | .071 | 0.002 | 0.011 | .023 | .117 |
| Hopkinton | -- | .145 | <.001 | .016 | .036 | .197 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- |
| Richmond | .045 | .072 | .011 | .067 | .081 | .276 |
| Sterling, CT | -- | .030 | -- | -- | .003 | .033 |
| Voluntown, CT | -- | .013 | -- | <.001 | .001 | .014 |
| West Greewich | .004 | .084 | <.001 | .038 | .011 | .137 |
| Subbasin total | 0.059 | 0.420 | 0.013 | 0.132 | 0.155 | 0.779 |
| **Lower Wood Subbasin** | | | | | | |
| Charlestown | 0.009 | 0.093 | <0.001 | 0.002 | 0.015 | 0.119 |
| Hopkinton | .016 | .101 | <.001 | .008 | .182 | .307 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- |
| Richmond | -- | .136 | .005 | .047 | .205 | .393 |
| Voluntown, CT | -- | -- | -- | <.001 | <.001 | <.001 |
| Subbasin total | 0.025 | 0.330 | 0.005 | 0.057 | 0.402 | 0.819 |

**Table 10.** Ground-water and surface-water withdrawals by town and subbasin in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.—Continued

[Public-supply, domestic, commercial, and industrial water withdrawals are from ground water (wells). For agriculture, irrigation-water withdrawals are assumed to be 81 percent from surface water (ponds and rivers), and 13 percent from ground water (wells). Livestock water withdrawals are assumed to be 9 percent from surface water and 82 percent from ground water. The remaining 6 percent for irrigation and 9 percent for livestock are estimated to be on public supply. All towns are in Rhode Island unless otherwise noted. Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, not applicable]

| Towns | Public-supply withdrawals (Mgal/d) | Self-supply withdrawals (Mgal/d) | | | | Total (Mgal/d) |
|---|---|---|---|---|---|---|
| | | Domestic | Commercial | Industrial | Agricultural | |
| **Lower Pawcatuck Subbasin** | | | | | | |
| Charlestown | -- | 0.068 | <0.001 | -- | 0.004 | 0.072 |
| Hopkinton | 0.012 | .255 | .001 | 0.024 | .071 | .363 |
| North Stonington, CT | -- | .206 | -- | .013 | .015 | .234 |
| Stonington, CT | -- | .029 | -- | .001 | .003 | .033 |
| Voluntown, CT | -- | .015 | -- | <.001 | .003 | .018 |
| Westerly | 3.236 | .046 | .109 | .139 | .053 | 3.583 |
| Subbasin total | 3.248 | 0.619 | 0.110 | 0.177 | 0.149 | 4.303 |
| **Pawcatuck Basin** | | | | | | |
| Basin total | 6.864 | 2.270 | 0.219 | 0.529 | 1.368 | 11.25 |

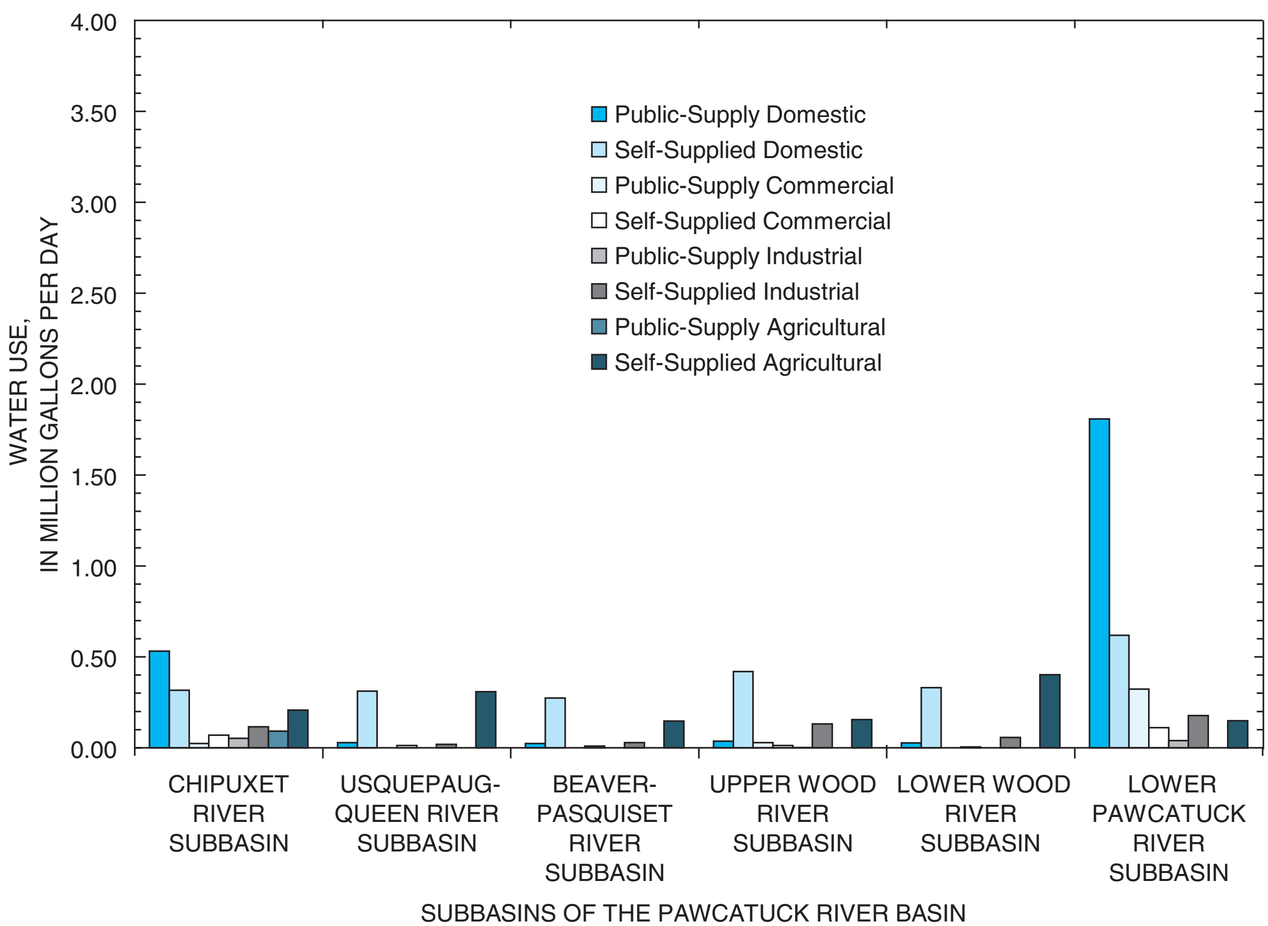



**Figure 7.** Public-supply and self-supplied domestic, commercial, industrial, and agricultural water use for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

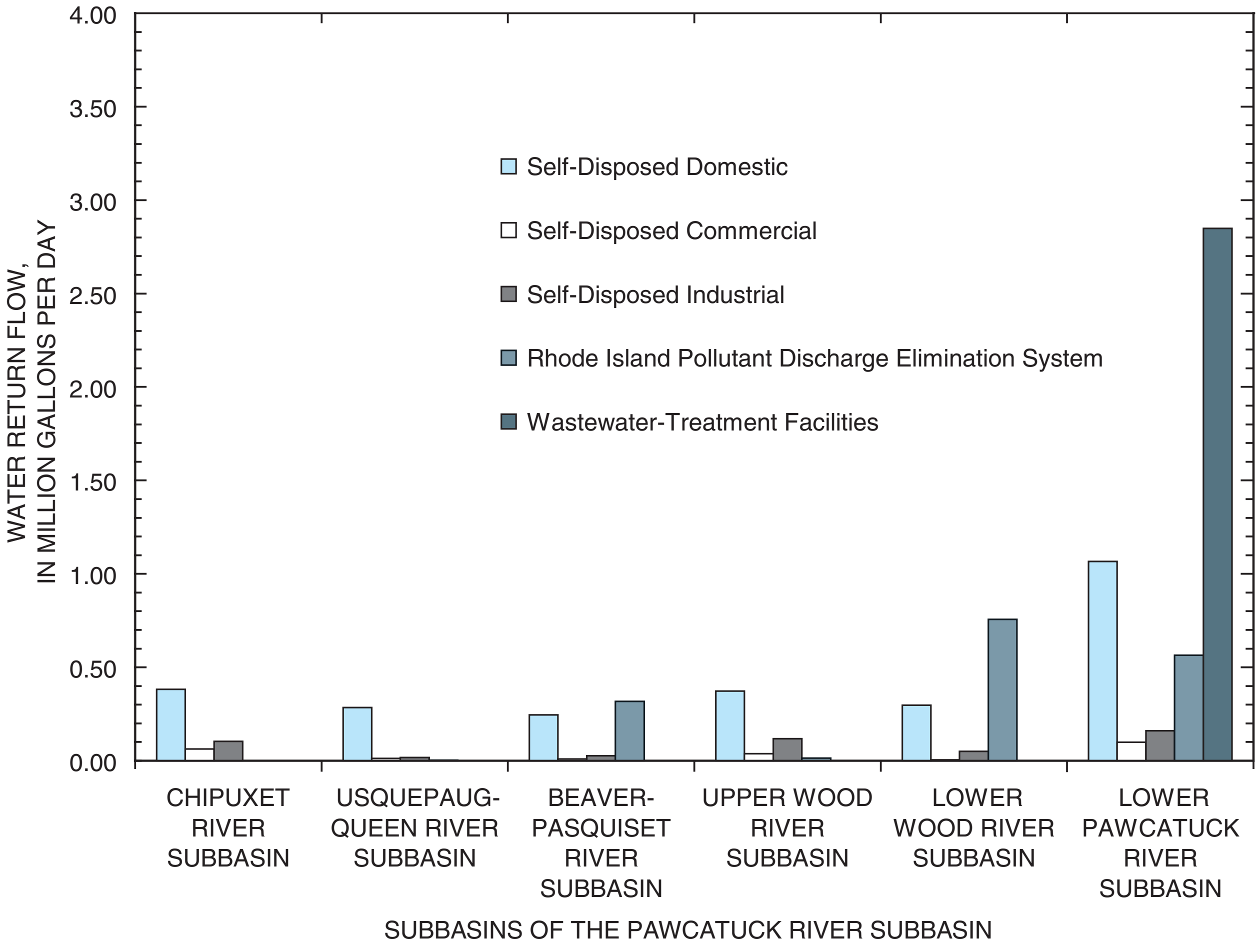



**Figure 8.** Wastewater-treatment facilities, Rhode Island Pollutant Discharge Elimination System, and self-disposed domestic, commercial, and industrial water return flow for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

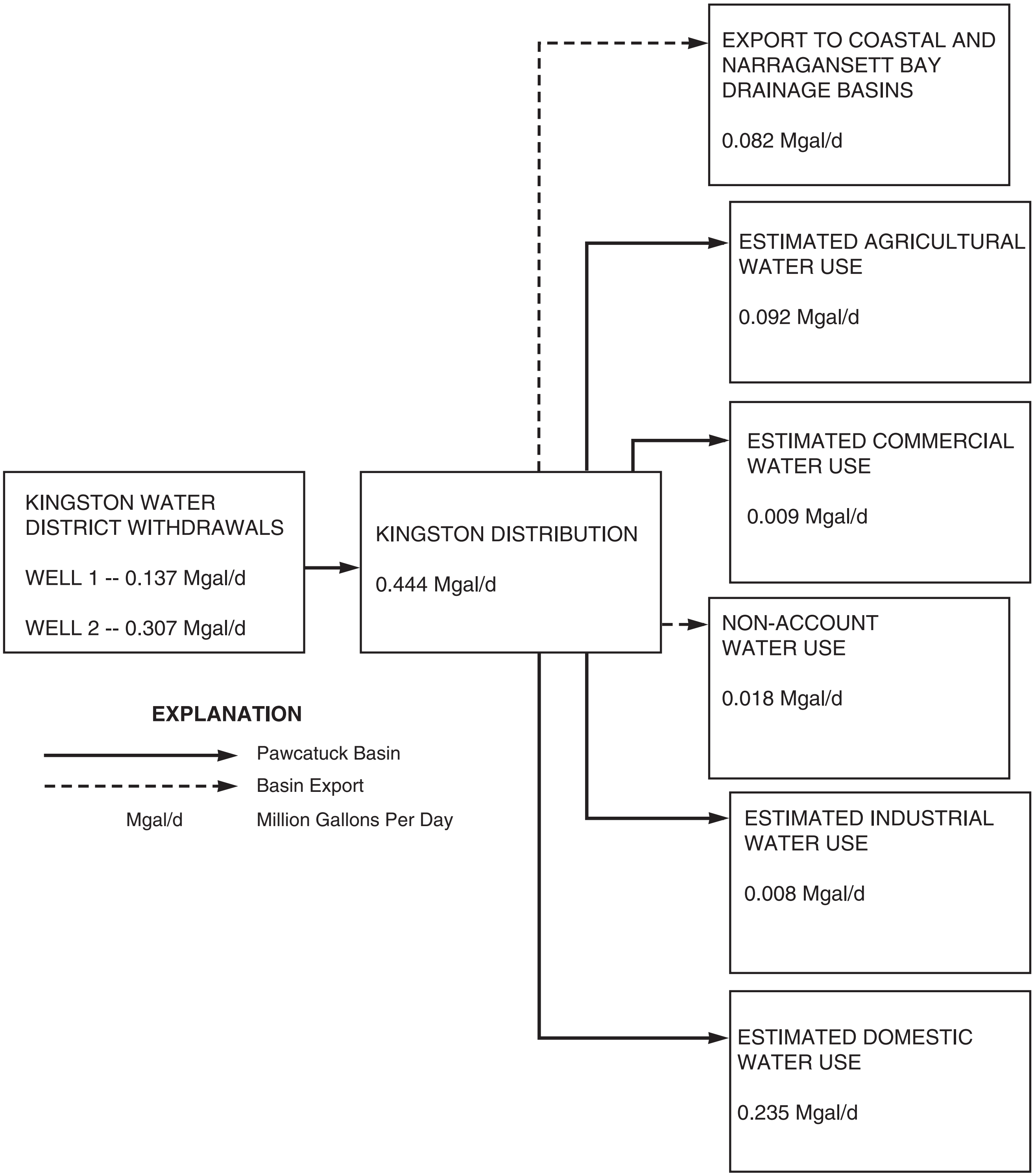



**Figure 9.** Kingston Water District withdrawals, distribution, and estimated water uses in the Pawcatuck Basin and basin exports, southern Rhode Island, 1995–99.

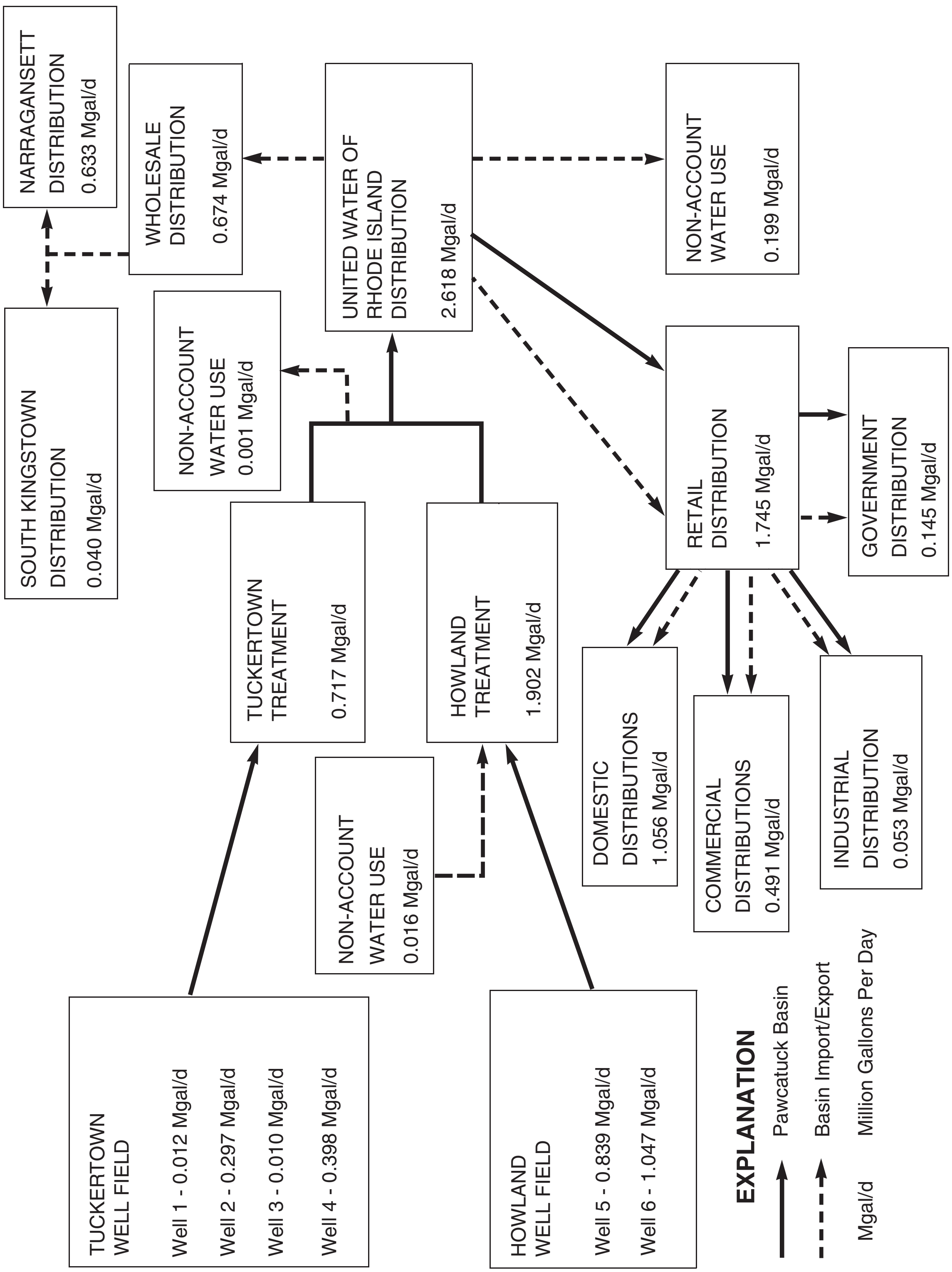



**Figure 10.** United Water of Rhode Island withdrawals, treatment, distributions, non-account water use in the Pawcatuck Basin and basin exports, southern Rhode Island, 1995–99.

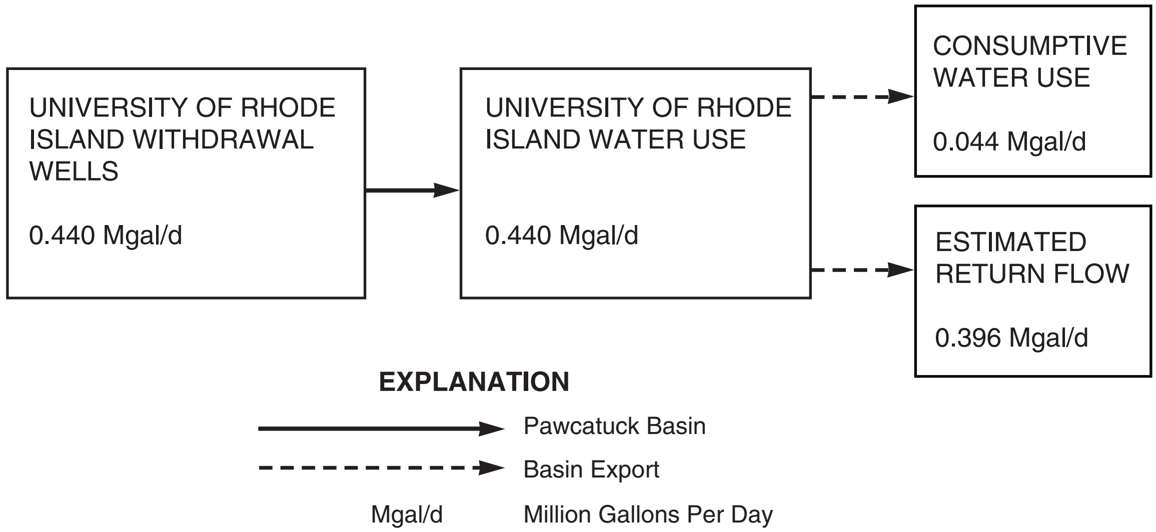



**Figure 11.** University of Rhode Island withdrawals, water uses, and estimated exported return flow in the Pawcatuck Basin, southern Rhode Island, 1995–99.

## Domestic Water Use

Domestic water use is the amount of water used by residential populations either served by public water supplies or self-supplied users on private wells. The domestic water-use category includes the public-water-supply deliveries to users within the political or hydrologic boundaries in the study area. Domestic withdrawals were estimated from the census coverages available through RIGIS and Connecticut MAGIC. The coverage has the 1990 populations that are self-supplied. The coverages then were separated by subbasin. To obtain the populations on public-water supplies, the self-supplied populations were subtracted from the total population in the subbasins. To calculate the water use for this category, population estimates in Rhode Island were multiplied by the water-use coefficients 71 gal/d/person for self-supplied domestic water use, and 67 gal/d/person for public-supply domestic water use, which were based on the 1990 National water-use compilation (Korzendorfer and Horn, 1995).

### Public-Supply Use

Because the water suppliers provide information on populations served within towns rather than subbasins, a Geographic Information System (GIS) was used to estimate subbasin populations on public supply by merging the 1990 census blocks that have the domestic populations on private wells with the subbasin coverage. The 1990 population that supplies its own water was subtracted from the total population for each subbasin. The ratio of the 1990 to 1995 through 1999 populations was applied in each subbasin to obtain the populations on public-supply and self-supplied water by subbasin for each town (table 1). Because limited withdrawal data are available for the 13 minor public suppliers in the basin, the water-use coefficient was applied to populations served for each entity (Korzendorfer and Horn, 1995).

Public-supply water use in the subbasins ranged from 0.024 Mgal/d (Beaver–Pasquiset subbasin) to 1.809 Mgal/d (Lower Pawcatuck subbasin) for domestic users. The estimated domestic uses of publicly supplied water by town are listed in table 11 and illustrated in figure 7.

### Self-Supplied Use

Domestic use of self-supplied water was calculated by merging the basin coverages with the U.S. Census 1990 population coverages obtained through RIGIS and Connecticut MAGIC. The 1990 census blocks have the population using private wells. The 1995 through 1999 population using self-supplied water for each subbasin was estimated from the 1990 population and 1995 through 1999 ratio of growth within each subbasin (table 1). Domestic-water withdrawals and use in the subbasins ranged from 0.273 Mgal/d (Beaver–Pasquiset subbasin) to 0.619 Mgal/d (Lower Pawcatuck subbasin) for self-supplied users (figs. 6 and 7, tables 10 and 11).

**Table 11.** Estimated water use by town and subbasin in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[All towns are in Rhode Island unless otherwise noted. Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, not applicable]

| Town | Domestic supply (Mgal/d) | | Commercial supply (Mgal/d) | | Industrial supply (Mgal/d) | | Agricultural supply (Mgal/d) | | Total (Mgal/d) |
|---|---|---|---|---|---|---|---|---|---|
| | Public | Self | Public | Self | Public | Self | Public | Self | |
| **Chipuxet Subbasin** | | | | | | | | | |
| Charlestown | 0.002 | 0.016 | -- | -- | -- | -- | -- | 0.002 | 0.020 |
| Exeter | .006 | .056 | -- | 0.003 | -- | 0.011 | -- | .033 | .109 |
| North Kingstown | .040 | .009 | -- | <.001 | -- | .002 | -- | .041 | .092 |
| Richmond | .001 | .022 | -- | .001 | -- | -- | -- | .027 | .051 |
| South Kingstown | .482 | .213 | 0.023 | .065 | 0.053 | .102 | 0.092 | .104 | 1.134 |
| Subbasin total | 0.531 | 0.316 | 0.023 | 0.069 | 0.053 | 0.115 | 0.092 | 0.207 | 1.406 |
| **Usquepaug–Queen Subbasin** | | | | | | | | | |
| East Greenwich | 0.002 | 0.001 | -- | -- | -- | -- | -- | <0.001 | 0.003 |
| Exeter | .011 | .209 | -- | 0.006 | -- | 0.002 | -- | .190 | .418 |
| North Kingstown | .009 | .001 | -- | .004 | -- | -- | -- | .005 | .019 |
| Richmond | .005 | .052 | -- | .001 | -- | -- | -- | .014 | .072 |
| South Kingstown | .001 | .032 | -- | .002 | -- | -- | -- | .098 | .133 |
| West Greenwich | -- | .017 | -- | -- | -- | .017 | -- | .001 | .035 |
| Subbasin total | 0.028 | 0.312 | -- | 0.013 | -- | 0.019 | -- | 0.308 | 0.680 |
| **Beaver–Pasquiset Subbasin** | | | | | | | | | |
| Charlestown | 0.011 | 0.099 | -- | 0.003 | -- | 0.002 | -- | 0.019 | 0.134 |
| Exeter | -- | .020 | -- | .005 | -- | -- | -- | .004 | .029 |
| Richmond | .012 | .153 | -- | .001 | -- | .027 | -- | .124 | .317 |
| South Kingstown | .001 | .001 | -- | -- | -- | -- | -- | -- | .002 |
| Subbasin total | 0.024 | 0.273 | -- | 0.009 | -- | 0.029 | -- | 0.147 | 0.482 |
| **Upper Wood Subbasin** | | | | | | | | | |
| Coventry | <0.001 | 0.005 | -- | -- | -- | -- | -- | <0.001 | 0.005 |
| Exeter | .009 | .071 | -- | 0.002 | -- | 0.011 | -- | .023 | .116 |
| Hopkinton | .010 | .145 | 0.001 | <.001 | -- | .016 | -- | .036 | .208 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Richmond | .009 | .072 | .027 | .011 | 0.001 | .067 | -- | .081 | .268 |
| Sterling, CT | .003 | .030 | -- | -- | -- | -- | -- | .003 | .036 |
| Voluntown, CT | .002 | .013 | -- | -- | -- | <.001 | -- | .001 | .016 |
| West Greewich | .004 | .084 | -- | <.001 | -- | .038 | -- | .011 | .137 |
| Subbasin total | 0.037 | 0.420 | 0.028 | 0.013 | 0.001 | 0.132 | -- | 0.155 | 0.786 |

**Table 11.** Estimated water use by town and subbasin in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.—Continued

[All towns are in Rhode Island unless otherwise noted. Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, not applicable]

| Town | Domestic supply (Mgal/d) | | Commercial supply (Mgal/d) | | Industrial supply (Mgal/d) | | Agricultural supply (Mgal/d) | | Total (Mgal/d) |
|---|---|---|---|---|---|---|---|---|---|
| | Public | Self | Public | Self | Public | Self | Public | Self | |
| Lower Wood Subbasin | | | | | | | | | |
| Charlestown | 0.003 | 0.093 | -- | <0.001 | -- | 0.002 | -- | 0.015 | 0.113 |
| Hopkinton | .016 | .101 | -- | <.001 | -- | .008 | -- | .182 | .307 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Richmond | .008 | .136 | -- | .005 | -- | .047 | -- | .205 | .401 |
| Voluntown, CT | -- | -- | -- | -- | -- | <.001 | -- | <.001 | <.001 |
| Subbasin total | 0.027 | 0.330 | -- | 0.005 | -- | 0.057 | -- | 0.402 | 0.821 |
| Lower Pawcatuck Subbasin | | | | | | | | | |
| Charlestown | 0.006 | 0.068 | -- | <0.001 | -- | -- | -- | 0.004 | 0.078 |
| Hopkinton | .023 | .255 | -- | .001 | -- | 0.024 | -- | .071 | .374 |
| North Stonington, CT | .059 | .206 | -- | -- | -- | .013 | -- | .015 | .293 |
| Stonington, CT | .323 | .029 | -- | -- | -- | .001 | -- | .003 | .356 |
| Voluntown, CT | <.001 | .015 | -- | -- | -- | <.001 | -- | .003 | .018 |
| Westerly | 1.398 | .046 | 0.323 | 0.109 | 0.039 | .139 | -- | .053 | 2.107 |
| Subbasin total | 1.809 | 0.619 | 0.323 | 0.110 | 0.039 | 0.177 | -- | 0.149 | 3.226 |
| Pawcatuck Basin | | | | | | | | | |
| Basin total | 2.456 | 2.270 | 0.374 | 0.219 | 0.093 | 0.529 | 0.092 | 1.368 | 7.401 |

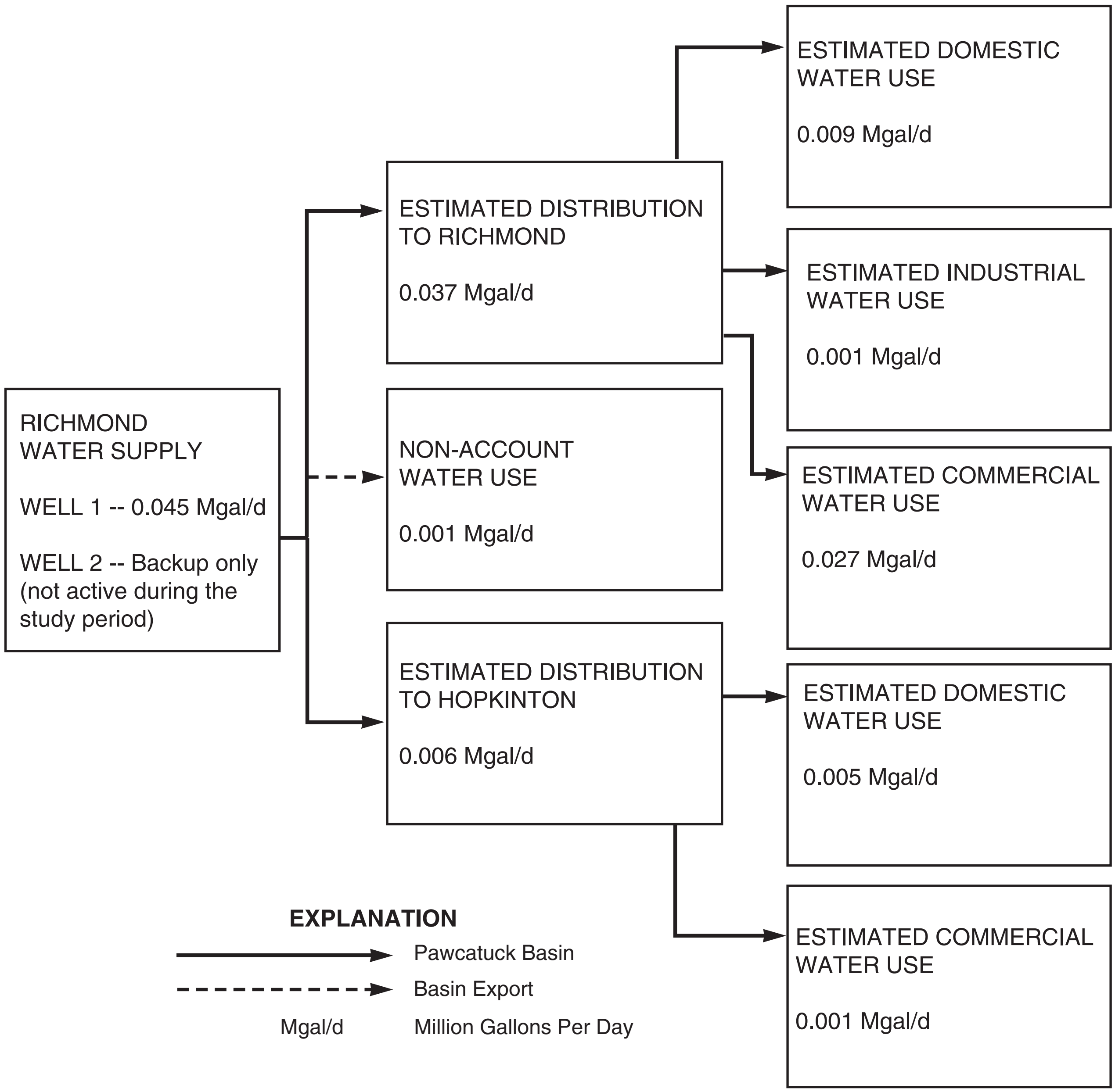



**Figure 12.** Richmond Water Supply withdrawals, estimated distributions, and estimated water uses in the Pawcatuck Basin, southern Rhode Island, 1995–99.

## Commercial and Industrial Water Use

Limited data are available on commercial and industrial water use from public-water supply and self-supplied systems, because withdrawals and use for these water-use categories (figs. 6 and 7) are not regulated in Rhode Island. Commercial and industrial water-use estimates, therefore, were derived from the total water calculated and divided by basin and subbasin for each town based on the land-use type. Commercial and industrial consumptive water use (table 12) is assumed to be 10 percent of the total water use (Solley and others, 1998).

**Table 12.** Consumptive water use by town and subbasin in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[All towns are in Rhode Island unless otherwise noted. Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, not applicable]

| Town/City | Domestic (Mgal/d) | | Commercial (Mgal/d) | | Industrial (Mgal/d) | | Agricultural (Mgal/d) | | Total (Mgal/d) |
|---|---|---|---|---|---|---|---|---|---|
| | Public | Self | Public | Self | Public | Self | Public | Self | |
| **Chipuxet Subbasin** | | | | | | | | | |
| Charlestown | <0.001 | 0.003 | -- | -- | -- | -- | -- | 0.002 | 0.005 |
| Exeter | .001 | .009 | -- | <0.001 | -- | 0.001 | -- | .033 | .044 |
| North Kingstown | <.001 | .008 | -- | <.001 | -- | <.001 | -- | .041 | .049 |
| Richmond | -- | .004 | -- | <.001 | -- | -- | -- | .027 | .031 |
| South Kingstown | .060 | .045 | 0.002 | .006 | 0.005 | .010 | 0.092 | .104 | .324 |
| Subbasin total | 0.061 | 0.069 | 0.002 | 0.006 | 0.005 | 0.011 | 0.092 | 0.207 | 0.453 |
| **Usquepaug–Queen Subbasin** | | | | | | | | | |
| East Greenwich | <0.001 | <.0001 | -- | -- | -- | -- | -- | <0.001 | <0.001 |
| Exeter | .001 | .032 | -- | 0.001 | -- | <0.001 | -- | .190 | .224 |
| North Kingstown | <.001 | .001 | -- | <.001 | -- | -- | -- | .005 | .006 |
| Richmond | -- | .009 | -- | <.001 | -- | -- | -- | .014 | .023 |
| South Kingstown | -- | .005 | -- | <.001 | -- | -- | -- | .098 | .103 |
| West Greenwich | -- | .003 | -- | -- | -- | .002 | -- | .001 | .006 |
| Subbasin total | 0.001 | 0.050 | -- | 0.001 | -- | 0.002 | -- | 0.308 | 0.362 |
| **Beaver–Pasquiset Subbasin** | | | | | | | | | |
| Charlestown | 0.001 | 0.015 | -- | <0.001 | -- | <0.001 | -- | 0.019 | 0.035 |
| Exeter | -- | .003 | -- | .001 | -- | -- | -- | .004 | .008 |
| Richmond | -- | .025 | -- | <.001 | -- | .003 | -- | .124 | .152 |
| South Kingstown | <.001 | <.001 | -- | -- | -- | -- | -- | -- | <.001 |
| Subbasin total | 0.001 | 0.043 | -- | 0.001 | -- | 0.003 | -- | 0.147 | 0.195 |
| **Upper Wood Subbasin** | | | | | | | | | |
| Coventry | -- | 0.001 | -- | -- | -- | -- | -- | <0.001 | 0.001 |
| Exeter | <0.001 | .012 | -- | <0.001 | -- | 0.001 | -- | .023 | .036 |
| Hopkinton | .001 | .022 | <0.001 | <.001 | -- | .002 | -- | .036 | .061 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Richmond | -- | .012 | .003 | .001 | <0.001 | .007 | -- | .081 | .104 |
| Sterling, CT | .001 | .004 | -- | -- | -- | -- | -- | .003 | .008 |
| Voluntown, CT | <.001 | .002 | -- | -- | -- | <.001 | -- | .001 | .003 |
| West Greenwich | <.001 | .013 | -- | <.001 | -- | .004 | -- | .011 | .028 |
| Subbasin total | 0.002 | 0.066 | 0.003 | 0.001 | <0.001 | 0.014 | -- | 0.155 | 0.241 |
| **Lower Wood Subbasin** | | | | | | | | | |
| Charlestown | <0.001 | 0.014 | -- | <0.001 | -- | <0.001 | -- | 0.015 | 0.029 |
| Hopkinton | .001 | .016 | -- | <.001 | -- | .001 | -- | .182 | .200 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Richmond | -- | .022 | -- | .001 | -- | .005 | -- | .205 | .233 |
| Voluntown, CT | -- | -- | -- | -- | -- | <.001 | -- | <.001 | <.001 |
| Subbasin total | 0.001 | 0.052 | -- | 0.001 | -- | 0.006 | -- | 0.402 | 0.462 |

**Table 12.** Consumptive water use by town and subbasin in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.—Continued

[All towns are in Rhode Island unless otherwise noted. Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, not applicable]

| Town/City | Domestic (Mgal/d) | | Commercial (Mgal/d) | | Industrial (Mgal/d) | | Agricultural (Mgal/d) | | Total (Mgal/d) |
|---|---|---|---|---|---|---|---|---|---|
| | Public | Self | Public | Self | Public | Self | Public | Self | |
| **Lower Pawcatuck Subbasin** | | | | | | | | | |
| Charlestown | <0.001 | 0.011 | -- | <0.001 | -- | -- | -- | 0.004 | 0.015 |
| Hopkinton | .001 | .040 | -- | <.001 | -- | 0.002 | -- | .071 | .114 |
| North Stonington, CT | .001 | .040 | -- | -- | -- | .001 | -- | .015 | .057 |
| Stonington, CT | .034 | .019 | -- | -- | -- | <.001 | -- | .003 | .056 |
| Voluntown, CT | -- | .002 | -- | -- | -- | <.001 | -- | .003 | .005 |
| Westerly | .129 | .076 | 0.032 | .011 | 0.004 | .014 | -- | .053 | .319 |
| Subbasin total | 0.165 | 0.188 | 0.032 | 0.011 | 0.004 | 0.017 | -- | 0.149 | 0.566 |
| **Pawcatuck Basin** | | | | | | | | | |
| Basin total | 0.231 | 0.468 | 0.037 | 0.021 | 0.009 | 0.053 | 0.092 | 1.368 | 2.279 |

## Public-Supply Use

Information on commercial and industrial use of public-supply water included metered (or reported) and unmetered water-use data. When the data were available, the public suppliers provided the delivery volume and the number of service connections for commercial and industrial water users. In some cases, the suppliers have reported the commercial and industrial users together, and in other cases the information was not available. Governmental water use is accounted for within the commercial water-use category, according to the Standard Industrial Classification (SIC) codes. For this study, government water use was entered as a separate distribution into NEWUDS, if the supplier collected the data to this level of detail. Because some water-supply district service areas are within one or more basins and subbasins, the public-supplied commercial and industrial water use were apportioned based on land-use area percentages (table 4). Land-use coverages from RIGIS were merged with the water-supply, town, and basin coverages to obtain the percentage of commercial and industrial land use within the supply districts for towns served in the Pawcatuck Basin. Commercial use of public-supply water ranged from 0 in several subbasins to 0.323 Mgal/d in the Lower Pawcatuck subbasin. Industrial use of public-supply water ranged from 0 in several subbasins to 0.053 Mgal/d in the Chipuxet subbasin.

## Self-Supplied Use

Commercial and industrial use of self-supplied water was calculated from industrial and commercial directories published by the Rhode Island Economic Development Corporation (*Export/Import Directory*, *High Tech Industries in Rhode Island, and Major Employers in Rhode Island*). Commercial and industrial water use was estimated for each town by identifying the number of employees for the industrial and commercial sectors for each SIC code and applying the U.S. Army Corp of Engineers' Institute for Water Resources Municipal and Industrial Needs (IWR-MAIN) water-use coefficient (in gallons/d/person) for each town (table 13) as described in Horn (2000). The estimated commercial and industrial entities on public water were subtracted from the total aggregate to obtain the estimated total self-supplied use for these categories. The results for commercial and industrial withdrawals and use are listed in tables 10 and 11. The total commercial and industrial water use estimated for a town was disaggregated by basin (table 7), and then by subbasin based on the industrial and commercial land-use area by town as listed in table 3. Commercial use of self-supplied water ranged from 0.005 Mgal/d (Lower Wood subbasin) to 0.110 Mgal/d in the Lower Pawcatuck subbasin (figs. 6 and 7). Industrial use of self-supplied water in the Pawcatuck Basin ranged from 0.019 Mgal/d in the Usquepaug–Queen subbasin to 0.177 Mgal/d in the Lower Pawcatuck subbasin (figs. 6 and 7). Commercial and industrial water use by subbasin and town are listed in table 11.

**Table 13.** Estimated water use per 2-digit Standard Industrial Classification code by town in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[IWR-MAIN, Institute for Water Resources-Municipal and Industrial Needs; Mgal/d, Million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, not applicable]

| 2-digit Standard Industrial Classification category and code | IWR-MAIN coeffi-cient | Estimated water use in Rhode Island towns (Mgal/d) | | | | | | | | | Water use in Connecticut towns (Mgal/d) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Charlestown | Coventry | Exeter | Hopkinton | North Kingstown | Richmond | South Kingstown | West Greenwich | Westerly | North Stonington | Sterling | Stonington | Voluntown |
| | | | | | | Industrial [20-39] | | | | | | | | |
| Food [20] | 469 | -- | -- | -- | -- | 0.011 | -- | 0.052 | -- | .006 | -- | -- | 0.002 | -- |
| Textile mills [22] | 315 | -- | 0.022 | -- | 0.025 | -- | 0.137 | .008 | 0.009 | .111 | -- | -- | .016 | -- |
| Finished apparel [23] | 13 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.001 | -- | -- |
| Wood, lumber [24] | 78 | -- | -- | -- | -- | .003 | -- | -- | -- | -- | -- | .001 | -- | -- |
| Furniture [25] | 30 | -- | -- | -- | -- | .008 | -- | -- | -- | -- | -- | -- | -- | -- |
| Paper products [26] | 863 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | .001 | -- | -- |
| Printing, publishing [27] | 42 | -- | -- | -- | .001 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Chemical products [28] | 289 | -- | .102 | -- | -- | .020 | -- | .003 | .068 | -- | -- | -- | -- | -- |
| Petroleum refining [29] | 1,045 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Rubber [30] | 119 | -- | -- | 0.024 | .021 | .109 | -- | -- | .003 | -- | -- | -- | -- | -- |
| Leather [31] | 148 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Stone, clay, glass, and concrete [32] | 202 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Primary metals [33] | 178 | -- | -- | -- | -- | -- | -- | -- | -- | .001 | -- | -- | -- | -- |
| Fabricated metal [34] | 95 | 0.004 | -- | -- | -- | .014 | -- | -- | -- | -- | 0.010 | -- | -- | -- |
| Machinery [35] | 58 | <.001 | .009 | -- | -- | .003 | .003 | -- | .058 | .012 | -- | -- | -- | -- |
| Electrical equipment [36] | 71 | -- | -- | -- | -- | .002 | -- | .110 | -- | .005 | .003 | -- | .001 | -- |
| Transportation equipment [37] | 63 | -- | -- | -- | -- | .087 | -- | .001 | -- | -- | -- | -- | .002 | -- |
| Instruments [38] | 66 | -- | .001 | -- | .001 | .030 | -- | .007 | -- | -- | -- | -- | -- | -- |
| Jewelry, precious metals [39] | 36 | -- | .008 | -- | -- | .001 | -- | -- | -- | .004 | -- | -- | -- | -- |
| Total industrial [20-39] | | 0.004 | 0.142 | 0.024 | 0.048 | 0.288 | 0.140 | 0.181 | 0.138 | 0.139 | 0.013 | 0.003 | 0.021 | -- |

**Table 13.** Estimated water use per 2-digit Standard Industrial Classification code by town in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.—Continued

[IWR-MAIN, Institute for Water Resources-Municipal and Industrial Needs; Mgal/d, Million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, not applicable]

| 2-digit Standard Industrial Classification category and code | IWR-MAIN coeffi-cient | Estimated water use in Rhode Island towns (Mgal/d) | | | | | | | | | Water use in Connecticut towns (Mgal/d) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Charlestown | Coventry | Exeter | Hopkinton | North Kingstown | Richmond | South Kingstown | West Greenwich | Westerly | North Stonington | Sterling | Stonington | Voluntown |
| Commercial [40-97] | | | | | | | | | | | | | | |
| Transportation, communication, utilities [40-49] | 51 | -- | -- | -- | -- | 0.001 | 0.006 | -- | 0.001 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 |
| Wholesale trade [50-51] | 58 | -- | -- | -- | -- | .008 | -- | -- | -- | -- | .016 | .002 | .017 | .004 |
| Retail trade [52-59] | 58 | -- | 0.034 | -- | -- | .038 | .013 | 0.014 | -- | .076 | .016 | .002 | .017 | .004 |
| Finance, insurance, real estate [60-67] | 71 | -- | -- | -- | -- | -- | -- | -- | -- | .028 | .003 | .001 | .011 | .001 |
| Services [70-89] | 106 | 0.016 | .034 | 0.017 | 0.001 | .119 | -- | .365 | -- | .091 | .043 | .015 | .140 | .011 |
| Public administration [91-97] | 71 | -- | -- | -- | -- | .022 | -- | -- | -- | -- | .005 | .001 | .021 | .001 |
| Total commercial [40-97] | | 0.016 | 0.068 | 0.017 | 0.001 | 0.188 | 0.019 | 0.379 | 0.001 | 0.196 | 0.086 | 0.022 | 0.196 | 0.022 |

## Agricultural Water Use

The estimated agricultural water use (livestock, crop irrigation, and golf-course irrigation) was obtained from information provided from the Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) formerly the Soil Conservation Service (SCS), and the RIDEM Division of Agriculture. The estimated value was calculated for each town and then disaggregated into the State basins and subbasins. Livestock withdrawals and use were assumed to be 9 percent from surface water (streams and ponds) and 82 percent from ground water (wells) based on previously estimated statewide livestock water use from the former Soil Conservation Service (1993), which is now referred to as the NRCS. Withdrawals and use for irrigation (golf courses and crops) were assumed to be 81 percent from surface water and 13 percent from ground water, based on previously estimated statewide irrigation water use (Soil Conservation Service, 1993). The remaining 9 percent of livestock use and 6 percent of irrigation use is assumed to be from public-supply distributions. Consumptive water use for agriculture was assumed to be 100 percent (table 11).

Livestock water requirements are also included in agricultural water use and include water-use estimates for each type of livestock (Laura Medalie, U.S. Geological Survey, written commun., 1995) multiplied by the number of livestock. Because the livestock and crop-irrigation data are reported in the *1997 Census of Agriculture* at the county level (U.S. Department of Agriculture, 1997a,b), the estimates were disaggregated by town and then basin on the basis of the number of farms in the town and the percentage of agricultural land use by town and by basin. The livestock water-use estimates represent a year-round usage. For this study, agricultural water use is assumed to be 100 percent consumed based on previous investigations (Horn and others, 1994). While it is estimated that 60 percent of livestock water use is consumptive, and 40 percent is returned to the ground water (Horn and others, 1994), this distinction was negligible for the subbasins in the Pawcatuck Basin. Livestock water use is minor in the basin, accounting for about 1.6 percent of the agricultural water use during the summer and about 3.4 percent of the agricultural water use during the study period.

Crop and golf-course irrigation were estimated with a method derived by the USGS water-use specialists in Vermont and New Hampshire during previous water-use compilations (Laura Medalie, U.S. Geological Survey, written commun., 2000). The percentage of agricultural land-use area for each town in the county was estimated on the basis of the agricultural land-use area in each town. The town acreage determined was subdivided by basin and subbasin. For the resulting acreage of crop irrigation for the portions of the towns in the Pawcatuck Basin, the coefficient determined by the SCS (1993) for the Pawcatuck Basin was applied. Crop acreage irrigated in the Pawcatuck Basin was assumed to be turf farming. For irrigated acreage for land areas in towns outside of the Pawcatuck Basin, it was assumed that 1 in/week/acre of water was needed to irrigate crop land, an average of 0.143 in/day/acre. The monthly deficiency of water was determined by subtracting the average monthly rainfall from the 0.143 in/day/acre needed for crop irrigation in the remaining basins in the State. Yardages for the golf courses, all of which are in Rhode Island, were collected by using the Web sites from WorldGolf.com (2002) and GolfCourse.com (2002). The coefficient of 0.0116 Mgal/d per 1,000 yards (Laura Medalie, U.S. Geological Survey, written commun., 2000) was applied to the golf courses for the towns in the Pawcatuck Basin. This coefficient used for this study was comparable to the metered (or reported) withdrawal data summarized for the 2000 water-use compilation for Massachusetts, where the average withdrawals were approximately 0.0117 Mgal/d per 1,000 yards. According to the SCS (1993), most of the irrigation occurred during June, July, and August; therefore, it was assumed that crop- and golf-course-irrigation water was used during these months. A concurrent USGS study is presently (2003) collecting data on crop and golf-course irrigation; however, the data were unavailable at the time of the data collection process for this study.

In the Pawcatuck Basin, some agricultural water use was from public-supply water. In the Kingston Water District, agricultural water use was one of the largest uses, consuming an average of 21 percent of the water distributions, and 0.092 Mgal/d in the basin during the study period (table 11).

Self-supplied agricultural water use was estimated to obtain the self-supplied water use by town and disaggregated by basin and subbasin. Self-supplied water withdrawals and use for agricultural ranged from 0.147 Mgal/d in the Beaver–Pasquiset subbasin to 0.402 Mgal/d in the Lower Wood subbasin (figs. 6 and 12, tables 10 and 11).

## Return Flow and Interbasin Transfers

In Rhode Island, commercial and industrial dischargers are required to report to the RIDEM Office of Water Resources the rates of water returned to the environment into surface water (usually to rivers) and ground water. The surface-water return flow in the Pawcatuck Basin was 4.505 Mgal/d, and the estimated ground-water return flow was 3.350 Mgal/d (table 14).

**Table 14.** Estimated public- and self-disposed domestic, commercial, and industrial, and metered return flow by subbasin in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[All towns are in Rhode Island unless otherwise noted. **Public disposal:** Wastewater collection to treatment plant. **Self-disposal:** Inflow to ground water. **RIPDES and wastewater treatment facilities:** Inflow to surface water. RIPDES, Rhode Island Pollution Discharge Elimination System; Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value less than value shown; --, not applicable]

| Town | Estimated domestic disposal (Mgal/d) | | Estimated commercial disposal (Mgal/d) | | Estimated industrial disposal (Mgal/d) | | Metered return flow | | Total self-disposal and return flow (Mgal/d) |
|---|---|---|---|---|---|---|---|---|---|
| | Public | Self | Public | Self | Public | Self | RIPDES | Wastewater-treatment facilities | |
| **Chipuxet Subbasin** | | | | | | | | | |
| Charlestown | 0.002 | 0.014 | -- | -- | -- | -- | -- | -- | 0.014 |
| Exeter | .003 | .050 | -- | 0.003 | -- | 0.010 | -- | -- | .063 |
| North Kingstown | <.001 | .044 | -- | <.001 | -- | .002 | -- | -- | .046 |
| Richmond | -- | .020 | -- | .001 | -- | -- | -- | -- | .021 |
| South Kingstown | .341 | .254 | 0.021 | .059 | 0.053 | .092 | -- | -- | .405 |
| Subbasin total | 0.346 | 0.382 | 0.021 | 0.063 | 0.053 | 0.104 | -- | -- | 0.549 |
| **Usquepaug–Queen Subbasin** | | | | | | | | | |
| East Greenwich | <0.001 | 0.002 | -- | -- | -- | -- | -- | -- | 0.002 |
| Exeter | .005 | .182 | -- | 0.005 | -- | 0.002 | 0.003 | -- | .192 |
| North Kingstown | .001 | .008 | -- | .004 | -- | -- | -- | -- | .012 |
| Richmond | -- | .049 | -- | .001 | -- | -- | -- | -- | .050 |
| South Kingstown | -- | .028 | -- | .002 | -- | -- | -- | -- | .030 |
| West Greenwich | -- | .015 | -- | -- | -- | .015 | -- | -- | .030 |
| Subbasin total | 0.006 | 0.284 | -- | 0.012 | -- | 0.017 | 0.003 | -- | 0.316 |
| **Beaver–Pasquiset Subbasin** | | | | | | | | | |
| Charlestown | 0.008 | 0.086 | -- | 0.003 | -- | 0.002 | -- | -- | 0.091 |
| Exeter | -- | .017 | -- | .005 | -- | -- | -- | -- | .022 |
| Richmond | -- | .141 | -- | .001 | -- | .024 | 0.318 | -- | .484 |
| South Kingstown | <.001 | .002 | -- | -- | -- | -- | -- | -- | .002 |
| Subbasin total | 0.008 | 0.246 | -- | 0.009 | -- | 0.026 | 0.318 | -- | 0.599 |
| **Upper Wood Subbasin** | | | | | | | | | |
| Coventry | -- | 0.004 | -- | -- | -- | -- | -- | -- | 0.004 |
| Exeter | 0.002 | .066 | -- | 0.002 | -- | 0.010 | -- | -- | .078 |
| Hopkinton | .006 | .126 | -- | .001 | -- | .014 | 0.005 | -- | .146 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Richmond | -- | .068 | -- | .034 | -- | .060 | .009 | -- | .171 |
| Sterling, CT | .004 | .024 | -- | -- | -- | -- | -- | -- | .024 |
| Voluntown, CT | <.001 | .012 | -- | -- | -- | <.001 | -- | -- | .012 |
| West Greenwich | .002 | .073 | -- | <.001 | -- | .034 | -- | -- | .107 |
| Subbasin total | 0.014 | 0.373 | -- | 0.037 | -- | 0.118 | 0.014 | -- | 0.542 |

**Table 14.** Estimated public- and self-disposed domestic, commercial, and industrial, and metered return flow by subbasin in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.—Continued

[All towns are in Rhode Island unless otherwise noted. **Public disposal:** Wastewater collection to treatment plant. **Self-disposal:** Inflow to ground water. **RIPDES and wastewater treatment facilities:** Inflow to surface water. RIPDES, Rhode Island Pollution Discharge Elimination System; Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; <, actual value less than value shown; --, not applicable]

| Town | Estimated domestic disposal (Mgal/d) | | Estimated commercial disposal (Mgal/d) | | Estimated industrial disposal (Mgal/d) | | Metered return flow | | Total self-disposal and return flow (Mgal/d) |
|---|---|---|---|---|---|---|---|---|---|
| | Public | Self | Public | Self | Public | Self | RIPDES | Wastewater-treatment facilities | |
| **Lower Wood Subbasin** | | | | | | | | | |
| Charlestown | <0.001 | 0.081 | -- | <0.001 | -- | 0.002 | 0.513 | -- | 0.596 |
| Hopkinton | .006 | .093 | -- | <.001 | -- | .007 | -- | -- | .100 |
| North Stonington, CT | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Richmond | -- | .123 | -- | .005 | -- | .042 | .243 | -- | .413 |
| Voluntown, CT | -- | <.001 | -- | -- | -- | <.001 | -- | -- | <.001 |
| Subbasin total | 0.006 | 0.297 | -- | 0.005 | -- | 0.051 | 0.756 | -- | 1.109 |
| **Lower Pawcatuck Subbasin** | | | | | | | | | |
| Charlestown | 0.001 | 0.062 | -- | <0.001 | -- | -- | -- | -- | 0.062 |
| Hopkinton | .007 | 0.229 | -- | .001 | -- | 0.022 | 0.564 | -- | .816 |
| North Stonington, CT | .006 | .224 | -- | -- | -- | .012 | -- | -- | .236 |
| Stonington, CT | .195 | .107 | -- | -- | -- | .001 | -- | 0.505 | .613 |
| Voluntown, CT | -- | .013 | -- | -- | -- | <.001 | -- | -- | .013 |
| Westerly | .733 | .432 | 0.291 | .098 | 0.035 | .125 | .001 | 2.344 | 3.000 |
| Subbasin total | 0.942 | 1.067 | 0.291 | 0.099 | 0.035 | 0.160 | 0.565 | 2.849 | 4.740 |
| **Pawcatuck Basin** | | | | | | | | | |
| Basin total | 1.322 | 2.649 | 0.312 | 0.225 | 0.088 | 0.476 | 1.656 | 2.849 | 7.855 |

## Site-Specific Return Flow

Small systems in Rhode Island that release water back to the environment are identified through the RIDEM Rhode Island Pollutant Discharge Elimination System (RIPDES), and some are required to report their discharges. Return-flow data were collected from RIDEM for these small systems in the Pawcatuck Basin (table 15). Data from individual treatment facilities, for example the wastewater-treatment plants, were collected, as recommended by Horn and Craft (1991). Discharge pipes dispose of water used during industrial and commercial processes (operations), but also include water condensation from air-conditioning systems. The total of RIPDES discharges in the Pawcatuck Basin was 1.656 Mgal/d, and ranged from 0.003 Mgal/d in the Usquepaug–Queen subbasin to 0.756 Mgal/d in the Lower Wood subbasin (table 15). There were no RIPDES sites in the Chipuxet subbasin during the 1995 through 1999 study period.

Monthly data were collected for public disposal wastewater-treatment facilities in or serving the towns in the Pawcatuck Basin (table 16). The wastewater-treatment facilities serving populations in the Pawcatuck Basin include the South Kingstown Wastewater-Treatment Facility, the Stonington Wastewater Pollution-Control Facility at Pawcatuck, and the Westerly Wastewater-Treatment Facility. The Westerly Wastewater-Treatment Facility is within the basin, discharges to the Pawcatuck River, and serves the community of Westerly. The average discharge for the study period to the Pawcatuck River from the Westerly system was 2.344 Mgal/d (table 16). The Stonington facility serves the village of Pawcatuck in the town of Stonington, CT, and the facility discharged an average of 0.505 Mgal/d. The South Kingstown Wastewater-Treatment Facility is in the West Narragansett Bay Drainage Basin, and accepts wastewater from populations in the Pawcatuck Basin.

**Table 15.** Return flows by subbasin for the Rhode Island Pollutant Discharge Elimination System sites in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[**Reference number:** The identifier for the site on figure 5. SIC, Standard Identification Code; WWTF, Wastewater-treatment facility; Mgal/d, Million gallons per day; <0.001, values not included in totals; <, actual value less than value shown--, not applicable]

| Return-flow site | Reference number | Town (locality) | Discharge permit number | Receiving water body | SIC code | Return flow 1995–99 (Mgal/d) |
|---|---|---|---|---|---|---|
| | | | Chipuxet Subbasin | | | |
| -- | -- | -- | -- | -- | -- | -- |
| Subbasin total | | | | | | -- |
| | | | Usquepaug–Queen Subbasin | | | |
| Ladd School WWTF | 1 | Exeter | RI0100081 | Queen River Tributary | 8211 | 0.003 |
| Subbasin total | | | | | | 0.003 |
| | | | Beaver–Pasquiset Subbasin | | | |
| Kenyon Industries, Inc. | 2 | Richmond (Kenyon) | RI000191 | Pawcatuck River | 2269 | 0.318 |
| Subbasin total | | | | | | 0.318 |
| | | | Upper Wood Subbasin | | | |
| Mobil Service Station | 3 | Richmond | RI0090174 | Pawcatuck River | 7542 | 0.009 |
| Rhode Island Department of Transportation | 4 | Hopkinton | RI0022136 | Unnamed Tributary to the Wood River | 4173 | .005 |
| Subbasin total | | | | | | 0.014 |
| | | | Lower Wood Subbasin | | | |
| Carolina Trout Hatchery | 5 | Charlestown (Carolina) | RI0001007 | White Brook | 0921 | 0.513 |
| Coastal Plastics | 6 | Hopkinton (Hope Valley) | RI0022080 | Wood River | 3089 | .014 |
| Green Plastics | 7 | Hopkinton (Hope Valley) | RI0001252 | Canochet Brook | 3081 | .229 |
| Subbasin total | | | | | | 0.756 |
| | | | Lower Pawcatuck Subbasin | | | |
| Ashaway Line and Twine Manufacturing Company | 8 | Hopkinton (Ashaway) | RI0021814 | Ashaway River | 2298 | <0.001 |
| Bradford Dye Company | 9 | Hopkinton (Bradford) | RI0000043 | Pawcatuck River | 2261 | .545 |
| The Imperial Home Decor Group | 10 | Hopkinton (Ashaway) | RI0020508 | Pawcatuck River | 5023 | .019 |
| Mobil Service Station | 11 | Westerly | RI0022098 | Pawcatuck River | 7542 | .001 |
| Subbasin total | | | | | | 0.565 |
| | | | Pawcatuck Basin | | | |
| Basin total | | | | | | 1.656 |

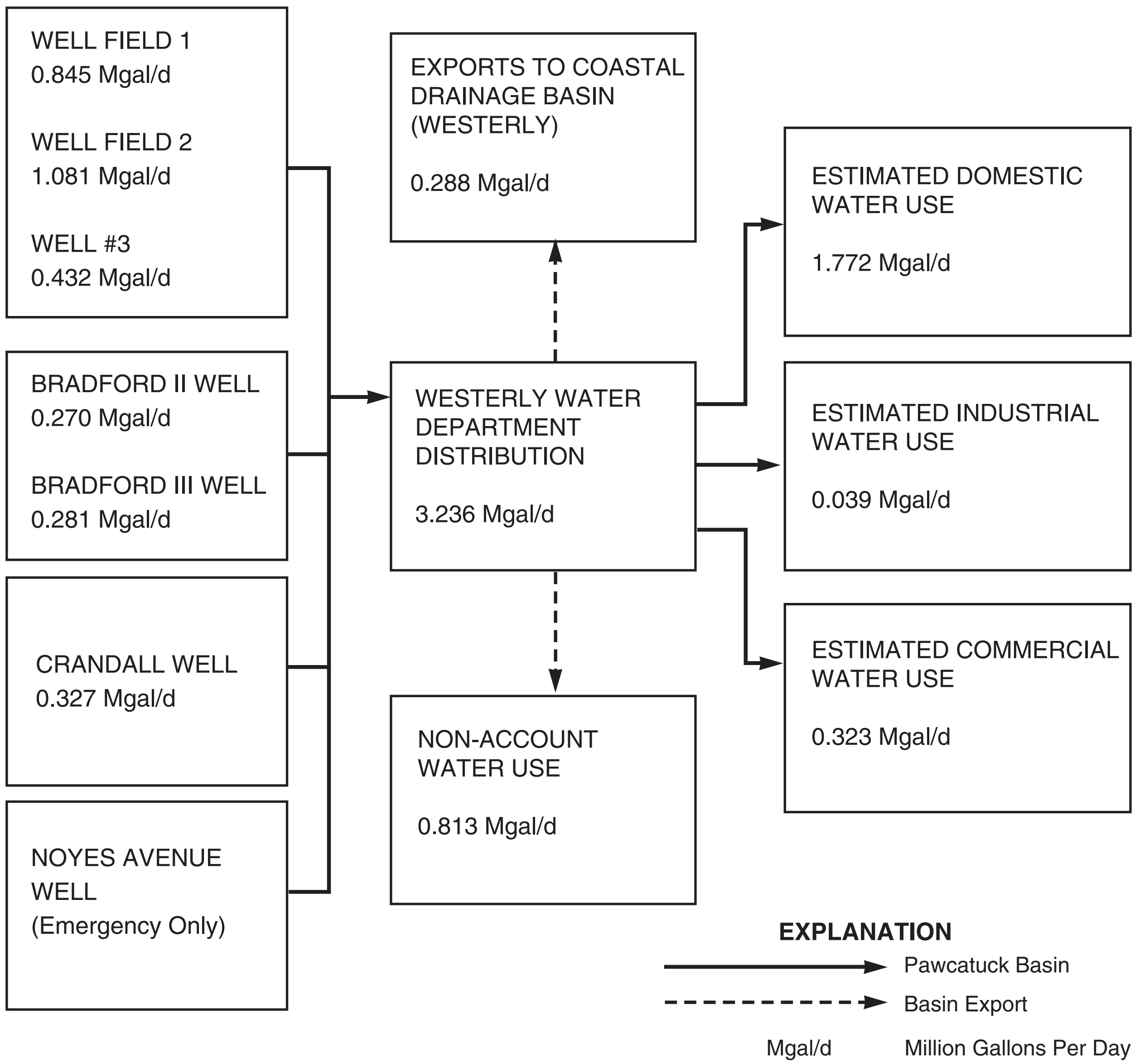



**Figure 13.** Westerly Water Department withdrawals, distributions, and estimated water uses in the Pawcatuck Basin and basin exports, southern Rhode Island and southeastern Connecticut, 1995–99.

**Table 16.** Return flow from wastewater-treatment facilities within and outside of the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[Mgal/d, Million gallons per day]

| Wastewater-treatment facility | Discharge permit number | Receiving water body (subbasin or basin) | Average discharge 1995–99 (Mgal/d) |
|---|---|---|---|
| Return flow to the Pawcatuck Basin | | | |
| Stonington Pawcatuck Water Pollution-Control Authority | CT0101290 | Pawcatuck River (Lower Pawcatuck subbasin) | 0.505 |
| Westerly Wastewater-Treatment Facility | RI0100064 | Pawcatuck River (Lower Pawcatuck subbasin) | 2.344 |
| Total | | | 2.849 |
| Return flow outside of the Pawcatuck Basin | | | |
| South Kingstown Regional Wastewater-Treatment Facility | RI0100374 | West Narragansett Bay Drainage Basin | 2.639 |
| Total | | | 2.639 |

## Aggregate Return Flow

Aggregate return flow was estimated for domestic, industrial, and commercial water use. Populations on public wastewater collection were used to determine the populations on septic systems (self-disposed) (table 1). It was assessed that 85 percent of the water used by domestic populations on septic systems was returned to ground water, based on the estimate that 15 percent of the water used was consumed (Solley and others, 1998). To estimate the amount of domestic self-disposed water, the population was multiplied by the water-use coefficient for self-supplied water use (71 gal/d/person), converted to Mgal/d, and multiplied by the 85 percent. The results for the domestic self-disposed water are summarized by town and subbasin in table 14, and illustrated by subbasin in figure 13. The other 15 percent of the water was assumed to be consumed (table 12). It is estimated that 90 percent of industrial and commercial return flow is disposed to ground water, where 10 percent is consumptive water use (Horn, 2000). A summary of the consumptive water use for domestic, commercial, industrial, and agricultural water users by subbasin is in table 12, and a summary of the return flow is in table 14.

## Interbasin Transfers

Wastewater collected from South Kingstown and treated at the South Kingstown facility was exported from the Pawcatuck Basin to the West Narragansett Bay Drainage Basin. Estimated populations on public disposal systems (table 1) and estimated publicly disposed industrial and commercial water from the Kingston Water District, URI, and UWRI (based on 80 percent of the water used in the Pawcatuck Basin) were used to determine the water exports, which resulted in approximately 2.487 Mgal/d exported from the basin (table 17). The total wastewater disposal from the South Kingstown facility was 2.639 Mgal/d, which discharges to West Narragansett Bay Drainage Basin (table 14). Also, parts of the wastewater-collection areas for Stonington and Westerly are outside of the Pawcatuck Basin, and about 2.080 Mgal/d of the wastewater is imported to the basin (table 17). Within the balance of the water withdrawals, use, unaccounted, consumptive, and return flows, there is a percentage error that is attributed to the summation of metered (or reported) and estimated water-use components for each category. Public water-supply withdrawals are metered (or reported), for example, but the use by subbasin is estimated, and then the return flow is metered (or reported) and estimated. Similarly, RIPDES data are metered (or reported) but the withdrawal and use is estimated.

**Table 17.** Summary of estimated water withdrawals, imports, exports, use, non-account water use, consumptive use, and return flow in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[**Non-account:** A loss of water through the water-supply system. **Consumptive use:** A basin export. **Net imports and exports:** The sum of the potable water and wastewater imports and exports; does not include non-account and consumptive water uses. AG, agricultural; COM, commercial; DOM, domestic; IND, industrial; Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; +, potable distribution and wastewater collection imported to subbasin and basin; -, potable distribution and wastewater collection exported from subbasin and basin; <, actual value is less than value shown; --, water use not applicable]

| Subbasin | Total water withdrawals (Mgal/d) | Potable water imports (+) and exports (-) (Mgal/d) | Total water use, public and self (Mgal/d) | | Consumptive use (Mgal/d) | Return flow (Mgal/d) | | Wastewater imports (+) and exports (-) (Mgal/d) | Net imports (+) and exports (-) (Mgal/d) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Use (DOM, COM, IND, AG) | Non-account (public use) | | Surface water | Ground water | | |
| Chipuxet | 4.212 | -2.258 | 1.406 | 0.548 | 0.453 | -- | 0.549 | -0.404 | -2.662 |
| Usquepaug–Queen | .674 | +.006 | .680 | -- | .362 | 0.003 | .313 | -.002 | +.004 |
| Beaver–Pasquiset | .463 | +.019 | .482 | -- | .195 | .318 | .281 | +.312 | +.331 |
| Upper Wood | .779 | +.008 | .786 | .001 | .241 | .014 | .528 | -.003 | +.005 |
| Lower Wood | .819 | +.002 | .821 | -- | .462 | .756 | .353 | +.750 | +.752 |
| Lower Pawcatuck | 4.303 | -.264 | 3.226 | .813 | .566 | 3.414 | 1.326 | +2.080 | +1.816 |
| Pawcatuck Basin total | 11.25 | -2.487 | 7.401 | 1.362 | 2.279 | 4.505 | 3.350 | +2.733 | +0.246 |

# Water Availability

During periods of little or no precipitation, streamflow is mostly from ground-water discharges, base flow, and direct run-off is assumed to be negligible. The computerized PART method (Rutledge, 1993, 1998) was used to obtain ground-water discharge to the streams during periods of little or no precipitation in the summer. Because water withdrawals can be higher during the summer, whereas the precipitation and ground-water discharge may be lower than average for the year, the ratio of the water withdrawals to water availability was assessed to determine the net availability of the water withdrawals to the hydrologic system during June, July, August, and September for the Pawcatuck Basin and subbasins. In addition, streamflow-depletion methods were applied to selected water-supply wells, and basin and subbasin water budgets for the study period were determined.

The water availability during times of little or no precipitation can be determined with streamflow data collected at the selected index stream-gaging stations. Water-availability estimates made from base-flow calculations are conservative estimates; actual streamflows are generally greater than base flow except for periods of little or no recharge from precipitation. In the Pawcatuck Basin, at least one stream-gaging station in each subbasin has at least 10 years of data (table 18). For the Lower Pawcatuck subbasin, however, the Pawcatuck River at Wood River Junction stream-gaging station (01117500) in the Lower Wood subbasin was used because of the regulation upstream of the Pawcatuck River at Westerly stream-gaging station (01118500). In addition to the Wood River Junction station, data from four other stream-gaging stations were used to determine water availability in the Chipuxet, Usquepaug–Queen, Beaver–Pasquiset, and Upper Wood subbasins: the Chipuxet River at West Kingston (station 01117350), Usquepaug River near Usquepaug (station 01117420), Beaver River near Usquepaug (station 01117468), and Wood River near Arcadia (station 01117800), respectively.

The PART program, a hydrograph-separation application, was used at the selected index stations to determine water availability based on the 75th, 50th, and 25th percentiles of the total base flow, the base flow minus the 7-day, 10-year flow (7Q10) criterion at the index station, and the base flow minus the Aquatic Base Flow (ABF) criterion at the index station (table 19). During the summer, portions of ground water drain out of the Pawcatuck Basin upstream of the Chipuxet and Usquepaug–Queen stream-gaging stations. For these stations, the program was run by using the surface-water drainage area, but the ground-water drainage areas were used for the base flow at the other stations. The differences in the surface and subsurface drainage areas in the summer were applied to the water availability calculated at the subbasins (table 5).

**Table 18.** U.S. Geological Survey stream-gaging stations and minimum streamflows in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[**USGS stream-gaging station number:** Identifier used in figure 5. **Drainage area:** Station drainage areas are from Socolow and others (2001). **Mean flow:** Water years are from October to September and may vary from the period of record in the data report. **Minimum flows:** 7Q10, 7-day, 10-year flow (G.W. Parker, U.S. Geological Survey, written commun., 2002); ABF, Aquatic Base Flow, based on the median of the monthly means; USGS, U.S. Geological Survey; Mgal/d, million gallons per day]

| USGS stream-gaging-station number | Station name | Drainage area ($mi^2$) | Mean flow (Mgal/d) [water years] | Minimum flows (Mgal/d) | |
|---|---|---|---|---|---|
| | | | | 7Q10 [water years] | ABF [water years] |
| 01117350 | Chipuxet River at West Kingston, RI | 9.99 | 13.71 [1974–2000] | 0.957 [1959–2001] | 5.994 [1974–2000] |
| 01117420 | Usquepaug River near Usquepaug, RI | 36.1 | 49.59 [1975–2000] | 3.608 [1959–2002] | 18.30 [1975–2000] |
| 01117468 | Beaver River near Usquepaug, RI | 8.87 | 13.77 [1975–2000] | 1.093 [1976–2002] | 4.746 [1975–2000] |
| 01117500 | Pawcatuck River at Wood River Junction, RI | 100 | 126.7 [1941–2000] | 17.07 [1942–2002] | 45.45 [1941–2000] |
| 01117800 | Wood River near Arcadia, RI | 35.2 | 49.53 [1964–1981; 1983–2000] | 4.209 [1964–1981; 1983–2000] | 13.84 [1964–1981; 1983–2000] |
| 01118500 | Pawcatuck River at Westerly, RI | 295 | 373.1 [1941–2000] | 41.83 [1942–2002] | 115.1 [1941–2000] |

Contributions of base flow from surficial deposits, till, and stratified sand and gravel for the index stations are based on previous work by the U.S. Geological Survey. The base-flow contributions from sand and gravel deposits at the index stations were 67 percent at the Chipuxet stream-gaging station (Johnston and Dickerman, 1985), 71 percent at the Usquepaug and Wood River Junction stream-gaging stations (Dickerman and others, 1997), 52 percent at the Beaver stream-gaging station (Gonthier and others, 1974), and 57 percent at the Arcadia stream-gaging station (Dickerman and Bell, 1993). The base-flow contributions from till deposits at the index stations were 33 percent at the Chipuxet stream-gaging station, 29 percent at the Usquepaug and Wood River Junction stream-gaging stations, 48 percent at the Beaver stream-gaging station, and 43 percent at the Arcadia stream-gaging station. The two contributions for June, July, August, and September were applied to the percentage of surficial deposits at each index station, and converted into a per unit area rate for the till areas and sand and gravel areas in the subbasins. The scenarios used to estimate the gross yield of base flow, as well as subtracting out the two low-flow criterias, resulted in various water-vailability values at each index station, which were present in the subbasin after applying the per unit area rates from the index station (table 19).

**Table 19.** Summer water availability for selected stream-gaging stations in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[7Q10, 7-day, 10-year flow; ABF, Aquatic Base Flow, based on the median of the August monthly means; Mgal/d, million gallons per day; --, values less than zero and not used]

| Summer base flow for selected index stations | Estimated gross yield (Mgal/d) | | | Estimated gross yield minus 7Q10 (Mgal/d) | | | Estimated gross yield minus ABF (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Chipuxet Stream-Gaging Station | | | | | | | | | |
| June | 14.01 | 9.273 | 6.653 | 13.04 | 8.303 | 5.683 | 8.020 | 3.279 | 0.660 |
| July | 8.822 | 4.918 | 3.676 | 7.852 | 3.948 | 2.706 | 2.828 | -- | -- |
| August | 7.123 | 5.070 | 3.296 | 6.153 | 4.100 | 2.326 | 1.130 | -- | -- |
| September | 5.134 | 4.191 | 3.012 | 4.164 | 3.221 | 2.043 | -- | -- | -- |
| Usquepaug Stream-Gaging Station | | | | | | | | | |
| June | 44.80 | 25.68 | 21.03 | 41.19 | 22.07 | 17.42 | 26.50 | 7.383 | 2.735 |
| July | 21.00 | 15.95 | 10.85 | 17.40 | 12.34 | 7.242 | 2.706 | -- | -- |
| August | 17.85 | 12.80 | 8.068 | 14.24 | 9.189 | 4.460 | -- | -- | -- |
| September | 16.39 | 11.02 | 7.570 | 12.78 | 7.412 | 3.962 | -- | -- | -- |
| Beaver Stream-Gaging Station | | | | | | | | | |
| June | 14.94 | 8.865 | 7.158 | 13.84 | 7.772 | 6.065 | 10.19 | 4.119 | 2.412 |
| July | 6.505 | 5.121 | 3.718 | 5.412 | 4.028 | 2.625 | 1.759 | .375 | -- |
| August | 5.334 | 3.653 | 2.399 | 4.242 | 2.560 | 1.306 | .588 | -- | -- |
| September | 4.358 | 3.188 | 2.160 | 3.265 | 2.065 | 1.067 | -- | -- | -- |
| Arcadia Stream-Gaging Station | | | | | | | | | |
| June | 41.41 | 28.46 | 21.42 | 37.21 | 24.25 | 17.22 | 27.57 | 14.62 | 7.582 |
| July | 20.38 | 16.09 | 11.65 | 16.18 | 11.89 | 7.445 | 6.546 | 2.252 | -- |
| August | 20.73 | 11.55 | 9.624 | 16.52 | 7.346 | 5.421 | 6.891 | -- | -- |
| September | 16.22 | 11.63 | 9.179 | 12.01 | 7.425 | 4.977 | 2.381 | -- | -- |
| Wood River Junction Stream-Gaging Station | | | | | | | | | |
| June | 115.5 | 90.40 | 72.00 | 98.40 | 73.33 | 54.93 | 70.02 | 44.95 | 26.55 |
| July | 66.45 | 51.32 | 41.36 | 49.39 | 34.25 | 24.29 | 21.00 | 5.862 | -- |
| August | 61.27 | 42.06 | 30.29 | 44.20 | 24.99 | 13.22 | 15.82 | -- | -- |
| September | 48.53 | 34.48 | 24.34 | 31.46 | 17.41 | 7.268 | 3.081 | -- | -- |

## Summer Water Availability by Subbasin

The water-availability estimates from the contributions of sand and gravel deposits and till deposits for all the scenarios at the 75th, 50th, and 25th percentiles in the Pawcatuck Basin and subbasins are presented in table 20. The water-availability estimates in July from sand and gravel deposits at the 50th percentile for the gross yield were 98.43, Mgal/d and 52.26 from the till deposits in the Pawcatuck Basin. By using the 7-day, 10-year low-flow criteria, the water-availability estimates in July from sand and gravel deposits at the 50th percentile for the gross yield were 72.25 Mgal/d, and 37.56 from the till deposits in the Pawcatuck Basin. (Total surficial deposits for the subbasins are presented in table 21.) The water availability from sand and gravel deposits for June, July, August, and September by subbasin at the 50th percentile for the gross yield, 7-day, 10-year low-flow criteria and Aquatic Base Flow criteria are illustrated in figure 14. The water availability from till deposits for June, July, August, and September by subbasin at the 50th percentile for the gross yield, 7-day, 10-year low-flow and Aquatic Base Flow criteria are illustrated in figure 15. The water availability from sand and gravel deposits and till deposits for June, July, August, and September by subbasin at the 50th percentile for the gross yield, 7-day, 10-year low-flow and Aquatic Base Flow criteria are illustrated in figure 16. Although the water availabilities were lower in September (Chipuxet, Usquepaug–Queen, Beaver–Pasquiset, Lower Wood, and Lower Pawcatuck subbasins) and August (Upper Wood subbasin) at the 50th percentile for the gross yield, there were more withdrawals in July (Chipuxet and Lower Pawcatuck subbasins) and August (Usquepaug–Queen, Beaver–Pasquiset, Upper Wood, and Lower Wood subbasins) than in September in the basin (table 22). The analysis of the water withdrawals-to-availabilities resulted in higher ratios in July (Chipuxet subbasin) and August (Usquepaug–Queen, Beaver–Pasquiset, Upper Wood, Lower Wood, and Lower Pawcatuck subbasins). The ratios of water withdrawals to availabilities for June, July, August, and September pertaining to the basin and subbasins are presented in table 23. The variation of the water withdrawal-to-availability ratios in the subbasins for July, August, and September are illustrated in figure 17. Water-availability estimates and water withdrawal to availability ratios were calculated for each subbasin. The cumulative withdrawals from upstream subbasins have not been accounted for in the water-availability calculations for the downstream subbasins.

In the Chipuxet subbasin, the estimated water availability for the gross yield at the 50th percentile ranged from 17.00 Mgal/d in September to 37.60 Mgal/d in June for the contributions from sand and gravel deposits, and ranged from 3.698 Mgal/d in September to 8.182 Mgal/d in June for the contributions from till deposits (table 20). The water availability in the subbasin at the 50th percentile for the gross yield ranged from 20.70 Mgal/d in September to 45.78 Mgal/d in June, and by using the 7Q10 criteria, ranged from 15.90 Mgal/d in September to 41.00 Mgal/d in June (table 21). The average water withdrawals for the Chipuxet subbasin ranged from 4.141 Mgal/d in September to 5.972 Mgal/d in July for the study period (table 22). The results for the ratios for the gross-yield scenario at the 50th percentile ranged from 0.109 in June to 0.252 in July, and by using the 7Q10 criteria, the ratios ranged from 0.121 in June to 0.314 in July (table 23).

In the Usquepaug–Queen subbasin, the estimated water availability for the gross yield at the 50th percentile ranged from 7.824 Mgal/d in September to 18.23 Mgal/d in June for the contributions from sand and gravel deposits, and ranged from 3.196 Mgal/d in September to 7.447 Mgal/d in June for the contributions from till deposits (table 20). The water availability in the subbasin at the 50th percentile for the gross yield ranged from 11.02 Mgal/d in September to 25.68 Mgal/d in June, and by using the 7Q10 criteria, ranged from 7.411 Mgal/d in September to 22.07 Mgal/d in June (table 21).The average water withdrawals for the Usquepaug–Queen subbasin ranged from 0.521 Mgal/d in September to 1.421 Mgal/d in August for the study period (table 22). The results for the ratios for the gross-yield scenario at the 50th percentile ranged from 0.032 in June to 0.111 in August, and by using the 7Q10 criteria, the ratios ranged from 0.038 in June to 0.155 in August (table 23).

In the Beaver–Pasquiset subbasin, the estimated water availability for the gross yield at the 50th percentile ranged from 7.200 Mgal/d in September to 20.02 Mgal/d in June for the contributions from sand and gravel deposits, and ranged from 2.913 Mgal/d in September to 8.102 Mgal/d in June for the contributions from till deposits (table 20). The water availability in the subbasin at the 50th percentile for the gross yield ranged from 10.11 Mgal/d in September to 28.12 Mgal/d in June, and by using the 7Q10 criteria, ranged from 6.647 Mgal/d in September to 24.65 Mgal/d in June (table 21).The average water withdrawals for the Beaver–Pasquiset subbasin ranged from 0.388 Mgal/d in September to 0.831 Mgal/d in August for the study period (table 22). The results for the ratios for the gross-yield scenario at the 50th percentile ranged from 0.019 in June to 0.072 in August, and by using the 7Q10 criteria the ratios ranged from 0.022 in June and 0.102 in August (table 23).

In the Upper Wood subbasin, the estimated water availability for the gross yield at the 50th percentile ranged from 12.80 Mgal/d in August to 31.55 Mgal/d in June for the contributions from sand and gravel deposits, and ranged from 10.55 Mgal/d in August to 25.99 Mgal/d in June for the contributions from till deposits (table 20). The water availability in the subbasin at the 50th percentile for the gross yield ranged from 23.35 Mgal/d in August to 57.54 Mgal/d in June, and by using the 7Q10 criteria, ranged from 14.85 Mgal/d in August to 49.04 Mgal/d in June (table 21).The average water withdrawals for the Upper Wood subbasin ranged from 0.702 Mgal/d in September to 1.175 Mgal/d in August for the study period (table 22). The results for the ratios for the gross-yield scenario at the 50th percentile ranged from 0.015 in June to 0.050 in August, and by using the 7Q10 criteria, the ratios ranged from 0.018 in June to 0.079 in August (table 23).

**Table 20.** Estimated gross yield, gross yield minus the 7-day, 10-year flow, and gross yield minus the Aquatic Base Flow of water availability for June, July, August, and September in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[7Q10, 7-day, 10-year flow; ABF, Aquatic Base Flow; Mgal/d, million gallons per day; --, values at station less than zero and not used]

| Subbasin | Estimated gross yield for June (Mgal/d) | | | Estimated gross yield minus 7Q10 for June (Mgal/d) | | | Estimated gross yield minus ABF for June (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Estimated Yields from Sand and Gravel Deposits | | | | | | | | | |
| Chipuxet subbasin[1] | 56.83 | 37.60 | 26.98 | 52.90 | 33.67 | 23.05 | 32.53 | 13.30 | 2.675 |
| Usquepaug–Queen subbasin[2] | 31.81 | 18.23 | 14.93 | 29.25 | 15.67 | 12.37 | 18.82 | 5.242 | 1.942 |
| Beaver–Pasquiset subbasin[3] | 33.73 | 20.02 | 16.17 | 31.27 | 17.55 | 13.70 | 23.02 | 9.303 | 5.447 |
| Upper Wood subbasin[4] | 45.91 | 31.55 | 23.75 | 41.25 | 26.89 | 19.09 | 30.57 | 16.21 | 8.406 |
| Lower Wood subbasin[5] | 30.18 | 23.63 | 18.82 | 25.72 | 19.17 | 14.36 | 18.30 | 11.75 | 6.939 |
| Lower Pawcatuck subbasin[5] | 54.77 | 42.88 | 34.15 | 46.68 | 34.79 | 26.06 | 33.21 | 21.32 | 12.60 |
| Total estimated yields from sand and gravel deposits | 253.2 | 173.9 | 134.8 | 227.1 | 147.7 | 108.6 | 156.4 | 77.12 | 38.01 |
| Estimated Yields from Till Deposits | | | | | | | | | |
| Chipuxet subbasin[1] | 12.37 | 8.182 | 5.870 | 11.51 | 7.326 | 5.015 | 7.076 | 2.893 | 0.582 |
| Usquepaug–Queen subbasin[2] | 12.99 | 7.447 | 6.100 | 11.95 | 6.401 | 5.053 | 7.685 | 2.141 | .793 |
| Beaver–Pasquiset subbasin[3] | 13.65 | 8.102 | 6.542 | 12.65 | 7.103 | 5.543 | 9.313 | 3.764 | 2.204 |
| Upper Wood subbasin[4] | 37.82 | 25.99 | 19.56 | 33.98 | 22.15 | 15.72 | 25.18 | 13.35 | 6.924 |
| Lower Wood subbasin[5] | 12.07 | 9.448 | 7.525 | 10.28 | 7.664 | 5.741 | 7.317 | 4.698 | 2.775 |
| Lower Pawcatuck subbasin[5] | 41.76 | 32.70 | 26.04 | 35.59 | 26.52 | 19.87 | 25.32 | 16.26 | 9.603 |
| Total estimated yields from till deposits | 130.7 | 91.87 | 71.64 | 116.0 | 77.16 | 56.94 | 81.90 | 43.11 | 22.88 |
| Estimated gross yields | 383.9 | 265.8 | 206.4 | 343.1 | 224.9 | 165.5 | 238.3 | 120.2 | 60.89 |

| Subbasin | Estimated gross yield for July (Mgal/d) | | | Estimated gross yield minus 7Q10 for July (Mgal/d) | | | Estimated gross yield minus ABF for July (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Estimated Yields from Sand and Gravel Deposits | | | | | | | | | |
| Chipuxet subbasin[1] | 35.78 | 19.94 | 14.91 | 31.84 | 16.01 | 10.97 | 11.47 | -- | -- |
| Usquepaug–Queen subbasin[2] | 14.91 | 11.33 | 7.703 | 12.35 | 8.763 | 5.142 | 1.921 | -- | -- |
| Beaver–Pasquiset subbasin[3] | 14.69 | 11.57 | 8.397 | 12.22 | 9.098 | 5.929 | 3.972 | 0.847 | -- |
| Upper Wood subbasin[4] | 22.60 | 17.84 | 12.91 | 17.94 | 13.18 | 8.254 | 7.257 | 2.497 | -- |
| Lower Wood subbasin[5] | 17.37 | 13.41 | 10.81 | 12.91 | 8.951 | 6.348 | 5.489 | 1.532 | -- |
| Lower Pawcatuck subbasin[5] | 31.52 | 24.34 | 19.62 | 23.43 | 16.25 | 11.52 | 9.963 | 2.781 | -- |
| Total estimated yields from sand and gravel deposits | 136.9 | 98.43 | 74.35 | 110.7 | 72.25 | 48.16 | 40.07 | 7.657 | -- |
| Estimated Yields from Till Deposits | | | | | | | | | |
| Chipuxet subbasin[1] | 7.784 | 4.339 | 3.243 | 6.928 | 3.483 | 2.388 | 2.495 | -- | -- |
| Usquepaug–Queen subbasin[2] | 6.091 | 4.626 | 3.146 | 5.045 | 3.579 | 2.100 | .785 | -- | -- |
| Beaver–Pasquiset subbasin[3] | 5.945 | 4.680 | 3.398 | 4.946 | 3.682 | 2.399 | 1.607 | 0.343 | -- |
| Upper Wood subbasin[4] | 18.61 | 14.69 | 10.64 | 14.78 | 10.85 | 6.798 | 5.978 | 2.057 | -- |
| Lower Wood subbasin[5] | 6.945 | 5.363 | 4.323 | 5.161 | 3.579 | 2.539 | 2.195 | .613 | -- |
| Lower Pawcatuck subbasin[5] | 24.04 | 18.56 | 14.96 | 17.86 | 12.39 | 8.786 | 7.597 | 1.120 | -- |
| Total estimated yields from till deposits | 69.42 | 52.26 | 39.71 | 54.72 | 37.56 | 25.01 | 20.66 | 4.133 | -- |
| Estimated gross yields | 206.3 | 150.7 | 114.1 | 165.4 | 109.8 | 73.17 | 60.73 | 11.79 | -- |

**Table 20.** Estimated gross yield, gross yield minus the 7-day, 10-year flow, and gross yield minus the Aquatic Base Flow of water availability for June, July, August, and September in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.—Continued

[7Q10, 7-day, 10-year flow; ABF, Aquatic Base Flow; Mgal/d, million gallons per day; --, values at station less than zero and not used]

| Subbasin | Estimated gross yield for August (Mgal/d) | | | Estimated gross yield minus 7Q10 for August (Mgal/d) | | | Estimated gross yield minus ABF for August (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Estimated Yields from Sand and Gravel Deposits | | | | | | | | | |
| Chipuxet subbasin[1] | 28.89 | 20.56 | 13.37 | 24.96 | 16.63 | 9.432 | 4.581 | -- | -- |
| Usquepaug–Queen subbasin[2] | 12.67 | 9.086 | 5.728 | 10.11 | 6.524 | 3.167 | -- | -- | -- |
| Beaver–Pasquiset subbasin[3] | 12.05 | 8.251 | 5.418 | 9.580 | 5.783 | 2.950 | 1.329 | -- | -- |
| Upper Wood subbasin[4] | 22.98 | 12.80 | 10.67 | 18.32 | 8.144 | 6.010 | 7.640 | -- | -- |
| Lower Wood subbasin[5] | 16.01 | 10.99 | 7.915 | 11.55 | 6.531 | 3.454 | 4.134 | -- | -- |
| Lower Pawcatuck subbasin[5] | 29.06 | 19.95 | 14.37 | 20.97 | 11.85 | 6.269 | 7.502 | -- | -- |
| Total estimated yields from sand and gravel deposits | 121.7 | 81.64 | 57.47 | 95.49 | 55.46 | 31.28 | 25.19 | -- | -- |
| Estimated Yields from Till Deposits | | | | | | | | | |
| Chipuxet subbasin[1] | 6.285 | 4.473 | 2.908 | 5.429 | 3.618 | 2.052 | 0.997 | -- | -- |
| Usquepaug–Queen subbasin[2] | 5.177 | 3.711 | 2.340 | 4.131 | 2.665 | 1.293 | -- | -- | -- |
| Beaver–Pasquiset subbasin[3] | 4.875 | 3.339 | 2.192 | 3.877 | 2.340 | 1.194 | .538 | -- | -- |
| Upper Wood subbasin[4] | 18.93 | 10.55 | 8.788 | 15.09 | 6.708 | 4.950 | 6.293 | -- | -- |
| Lower Wood subbasin[5] | 6.403 | 4.396 | 3.165 | 4.619 | 2.612 | 1.381 | 1.653 | -- | -- |
| Lower Pawcatuck subbasin[5] | 22.16 | 15.21 | 10.95 | 15.99 | 9.038 | 4.780 | 5.721 | -- | -- |
| Total estimated yields from till deposits | 63.83 | 41.68 | 30.34 | 49.14 | 26.98 | 15.65 | 15.20 | -- | -- |
| Estimated gross yields | 185.5 | 123.3 | 87.81 | 144.6 | 82.44 | 46.93 | 40.39 | -- | -- |

**Table 20.** Estimated gross yield, gross yield minus the 7-day, 10-year flow, and gross yield minus the Aquatic Base Flow of water availability for June, July, August, and September in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.—Continued

[7Q10, 7-day, 10-year flow; ABF, Aquatic Base Flow; Mgal/d, million gallons per day; --, values at station less than zero and not used]

| Subbasin | Estimated gross yield for September (Mgal/d) | | | Estimated gross yield minus 7Q10 for September (Mgal/d) | | | Estimated gross yield minus ABF for September (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Estimated Yields from Sand and Gravel Deposits | | | | | | | | | |
| Chipuxet subbasin[1] | 20.82 | 17.00 | 12.22 | 16.89 | 13.06 | 8.283 | -- | -- | -- |
| Usquepaug–Queen subbasin[2] | 11.63 | 7.824 | 5.375 | 9.073 | 5.262 | 2.813 | -- | -- | -- |
| Beaver–Pasquiset subbasin[3] | 9.843 | 7.200 | 4.878 | 7.375 | 4.732 | 2.410 | -- | -- | -- |
| Upper Wood subbasin[4] | 17.98 | 12.89 | 10.18 | 13.32 | 8.231 | 5.517 | 2.639 | -- | -- |
| Lower Wood subbasin[5] | 12.68 | 9.012 | 6.360 | 8.222 | 4.551 | 1.899 | .805 | -- | -- |
| Lower Pawcatuck subbasin[5] | 23.02 | 16.36 | 11.54 | 14.92 | 8.259 | 3.447 | 1.461 | -- | -- |
| Total estimated yields from sand and gravel deposits | 95.97 | 70.29 | 50.55 | 69.80 | 44.10 | 24.37 | 4.905 | -- | -- |
| Estimated Yields from Till Deposits | | | | | | | | | |
| Chipuxet subbasin[1] | 4.530 | 3.698 | 2.658 | 3.674 | 2.842 | 1.802 | -- | -- | -- |
| Usquepaug–Queen subbasin[2] | 4.752 | 3.196 | 2.195 | 3.706 | 2.149 | 1.149 | -- | -- | -- |
| Beaver–Pasquiset subbasin[3] | 3.983 | 2.913 | 1.974 | 2.984 | 1.915 | .975 | -- | -- | -- |
| Upper Wood subbasin[4] | 14.81 | 10.62 | 8.383 | 10.97 | 6.780 | 4.545 | 2.174 | -- | -- |
| Lower Wood subbasin[5] | 5.072 | 3.604 | 2.543 | 5.161 | 3.579 | 2.539 | .322 | -- | -- |
| Lower Pawcatuck subbasin[5] | 17.55 | 12.47 | 8.802 | 11.38 | 6.298 | 2.629 | 1.114 | -- | -- |
| Total estimated yields from till deposits | 50.70 | 36.50 | 26.56 | 37.88 | 23.56 | 13.64 | 3.610 | -- | -- |
| Estimated gross yields | 146.7 | 106.8 | 77.11 | 107.7 | 67.66 | 38.01 | 8.515 | -- | -- |

[1]Estimated gross yields based on base flow from the Chipuxet stream-gaging station, 1974 through 2000.
[2]Estimated gross yields based on base flow from the Usquepaug stream-gaging station, 1975 through 2000.
[3]Estimated gross yields based on base flow from the Beaver stream-gaging station, 1975 through 2000.
[4]Estimated gross yields based on base flow from the Arcadia stream-gaging station, 1964 through 1981 and 1983 through 2000.
[5]Estimated gross yields based on base flow from the Wood River Junction stream-gaging station, 1941 through 2000.

**Table 21.** Estimated gross yield of water availability for June, July, August, and September in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[7Q10, 7-day, 10-year; ABF, Aquatic Base Flow; Mgal/d, Million gallons per day; --, values at station less than zero and not used]

| Subbasin | Estimated gross yield for June (Mgal/d) | | | Estimated gross yield minus 7Q10 for June (Mgal/d) | | | Estimated gross yield minus ABF for June (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Chipuxet subbasin[1] | 69.20 | 45.78 | 32.85 | 64.41 | 41.00 | 28.06 | 39.61 | 16.19 | 3.257 |
| Usquepaug–Queen subbasin[2] | 44.80 | 25.68 | 21.03 | 41.20 | 22.07 | 17.42 | 26.50 | 7.383 | 2.735 |
| Beaver–Pasquiset subbasin[3] | 47.38 | 28.12 | 22.71 | 43.92 | 24.65 | 19.24 | 32.33 | 13.07 | 7.651 |
| Upper Wood subbasin[4] | 83.73 | 57.54 | 43.31 | 75.23 | 49.04 | 34.81 | 55.75 | 29.56 | 15.33 |
| Lower Wood subbasin[5] | 42.25 | 33.08 | 26.34 | 36.00 | 26.83 | 20.10 | 25.62 | 16.45 | 9.71 |
| Lower Pawcatuck subbasin[5] | 96.53 | 75.58 | 60.19 | 82.27 | 61.31 | 45.93 | 58.53 | 37.58 | 22.20 |
| Total estimated yields | 383.9 | 265.8 | 206.4 | 343.1 | 224.9 | 165.6 | 238.3 | 120.2 | 60.88 |

**Table 21.** Estimated gross yield of water availability for June, July, August, and September in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.—Continued

[7Q10, 7-day, 10-year; ABF, Aquatic Base Flow; Mgal/d, Million gallons per day; --, values at station less than zero and not used]

| Subbasin | Estimated gross yield for July (Mgal/d) | | | Estimated gross yield minus 7Q10 for July (Mgal/d) | | | Estimated gross yield minus ABF for July (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Chipuxet subbasin[1] | 43.56 | 24.28 | 18.15 | 38.77 | 19.49 | 13.36 | 13.96 | -- | -- |
| Usquepaug–Queen subbasin[2] | 21.00 | 15.96 | 10.85 | 17.40 | 12.34 | 7.242 | 2.706 | -- | -- |
| Beaver–Pasquiset subbasin[3] | 20.64 | 16.25 | 11.80 | 17.17 | 12.78 | 8.328 | 5.579 | 1.190 | -- |
| Upper Wood subbasin[4] | 41.21 | 32.53 | 23.55 | 32.72 | 24.03 | 15.05 | 13.24 | 4.554 | -- |
| Lower Wood subbasin[5] | 24.32 | 18.77 | 15.13 | 18.07 | 12.53 | 8.887 | 7.684 | 2.145 | -- |
| Lower Pawcatuck subbasin[5] | 55.56 | 42.90 | 34.58 | 41.29 | 28.64 | 20.31 | 17.56 | 3.901 | -- |
| Total estimated yields | 206.3 | 150.7 | 114.1 | 165.4 | 109.8 | 73.18 | 60.73 | 11.79 | -- |

| Subbasin | Estimated gross yield for August (Mgal/d) | | | Estimated gross yield minus 7Q10 for August (Mgal/d) | | | Estimated gross yield minus ABF for August (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Chipuxet subbasin[1] | 35.18 | 25.03 | 16.28 | 30.39 | 20.25 | 11.48 | 5.578 | -- | -- |
| Usquepaug–Queen subbasin[2] | 17.85 | 12.80 | 8.068 | 14.24 | 9.189 | 4.460 | -- | -- | -- |
| Beaver–Pasquiset subbasin[3] | 16.92 | 11.59 | 7.610 | 13.46 | 8.123 | 4.144 | 1.867 | -- | -- |
| Upper Wood subbasin[4] | 41.91 | 23.35 | 19.46 | 33.41 | 14.85 | 10.96 | 13.93 | -- | -- |
| Lower Wood subbasin[5] | 22.41 | 15.39 | 11.08 | 16.17 | 9.143 | 4.835 | 5.787 | -- | -- |
| Lower Pawcatuck subbasin[5] | 51.22 | 35.16 | 25.32 | 36.96 | 20.89 | 11.05 | 13.22 | -- | -- |
| Total estimated yields | 185.5 | 123.3 | 87.82 | 144.6 | 82.44 | 46.93 | 40.38 | -- | -- |

| Subbasin | Estimated gross yield for September (Mgal/d) | | | Estimated gross yield minus 7Q10 for September (Mgal/d) | | | Estimated gross yield minus ABF for September (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Chipuxet subbasin[1] | 25.35 | 20.70 | 14.88 | 20.56 | 15.90 | 10.08 | -- | -- | -- |
| Usquepaug–Queen subbasin[2] | 16.38 | 11.02 | 7.570 | 12.78 | 7.411 | 3.962 | -- | -- | -- |
| Beaver–Pasquiset subbasin[3] | 13.83 | 10.11 | 6.852 | 10.36 | 6.647 | 3.385 | -- | -- | -- |
| Upper Wood subbasin[4] | 32.79 | 23.51 | 18.56 | 24.29 | 15.01 | 10.06 | 4.813 | -- | -- |
| Lower Wood subbasin[5] | 17.75 | 12.62 | 8.903 | 13.38 | 8.130 | 4.438 | 1.127 | -- | -- |
| Lower Pawcatuck subbasin[5] | 40.57 | 28.83 | 20.34 | 26.30 | 14.56 | 6.076 | 2.575 | -- | -- |
| Total estimated yields | 146.7 | 106.8 | 77.10 | 107.7 | 67.66 | 38.00 | 8.515 | -- | -- |

[1]Estimated gross yields based on base flow from the Chipuxet stream-gaging station, 1974 through 2000.

[2]Estimated gross yields based on base flow from the Usquepaug stream-gaging station, 1975 through 2000.

[3]Estimated gross yields based on base flow from the Beaver stream-gaging station, 1975 through 2000.

[4]Estimated gross yields based on base flow from the Arcadia stream-gaging station, 1964 through 1981 and 1983 through 2000.

[5]Estimated gross yields based on base flow from the Wood River Junction stream-gaging station, 1941 through 2000.

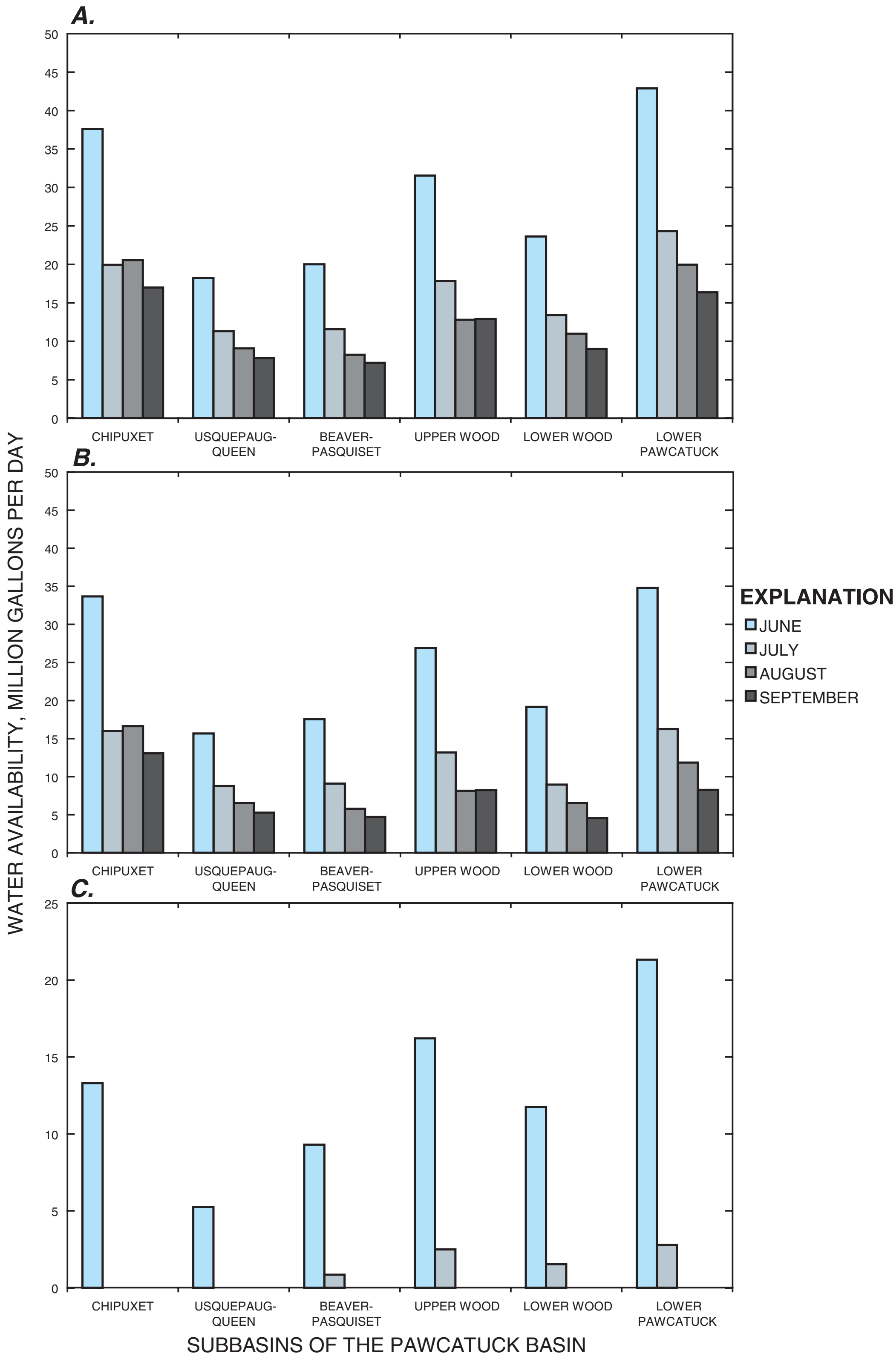



**Figure 14.** Estimated water availability for June, July, August, and September from sand and gravel deposits for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, based on the *A*, 50th percentile; *B*, 50th percentile minus the 7-day, 10-year flow criteria; and *C*, 50th percentile minus the Aquatic Base Flow criteria.

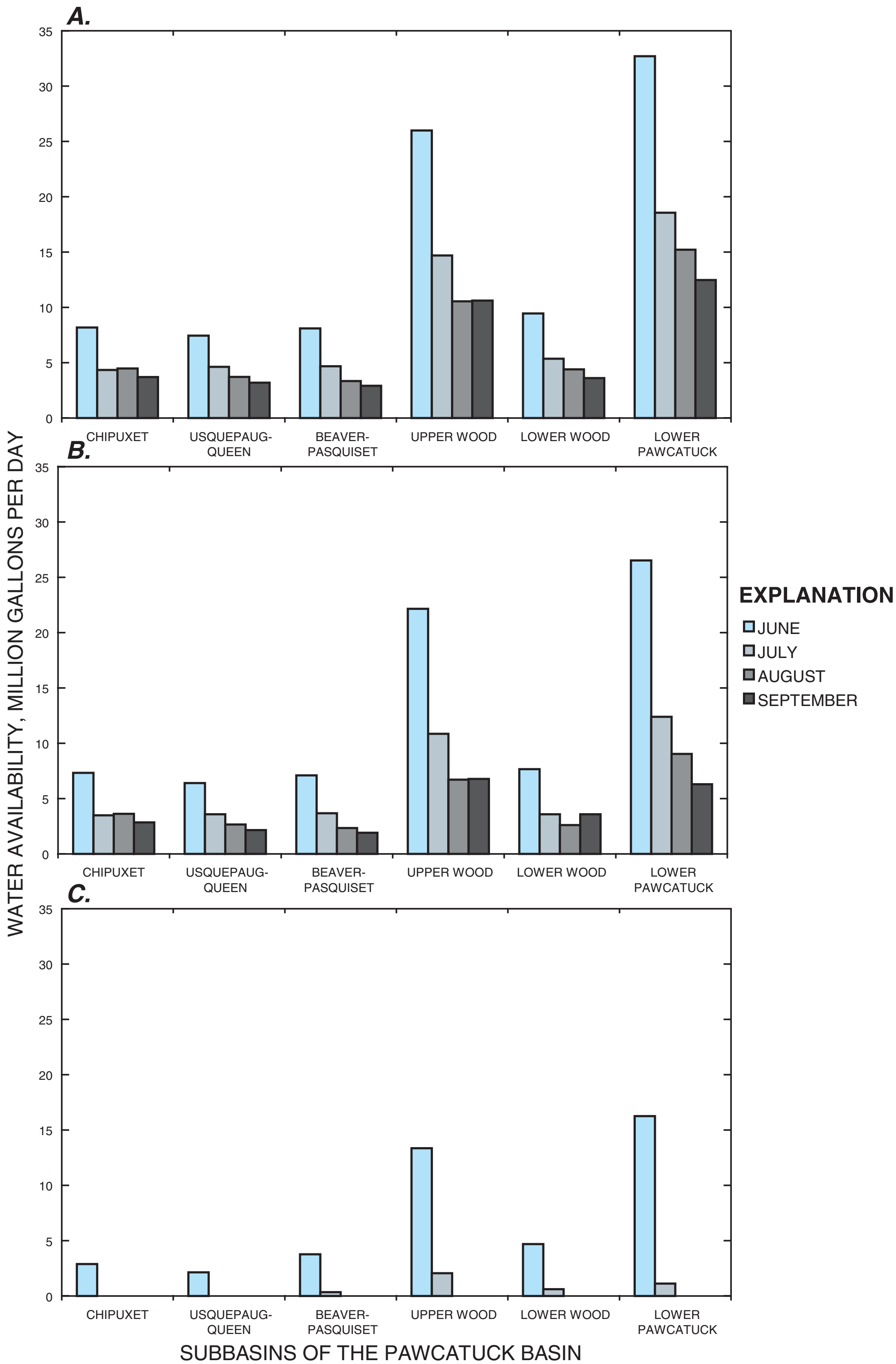



**Figure 15.** Estimated water availability for June, July, August, and September from till deposits for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, based on the *A*, 50th percentile; *B*, 50th percentile minus the 7-day, 10-year flow criteria; and *C*, 50th percentile minus the Aquatic Base Flow criteria.

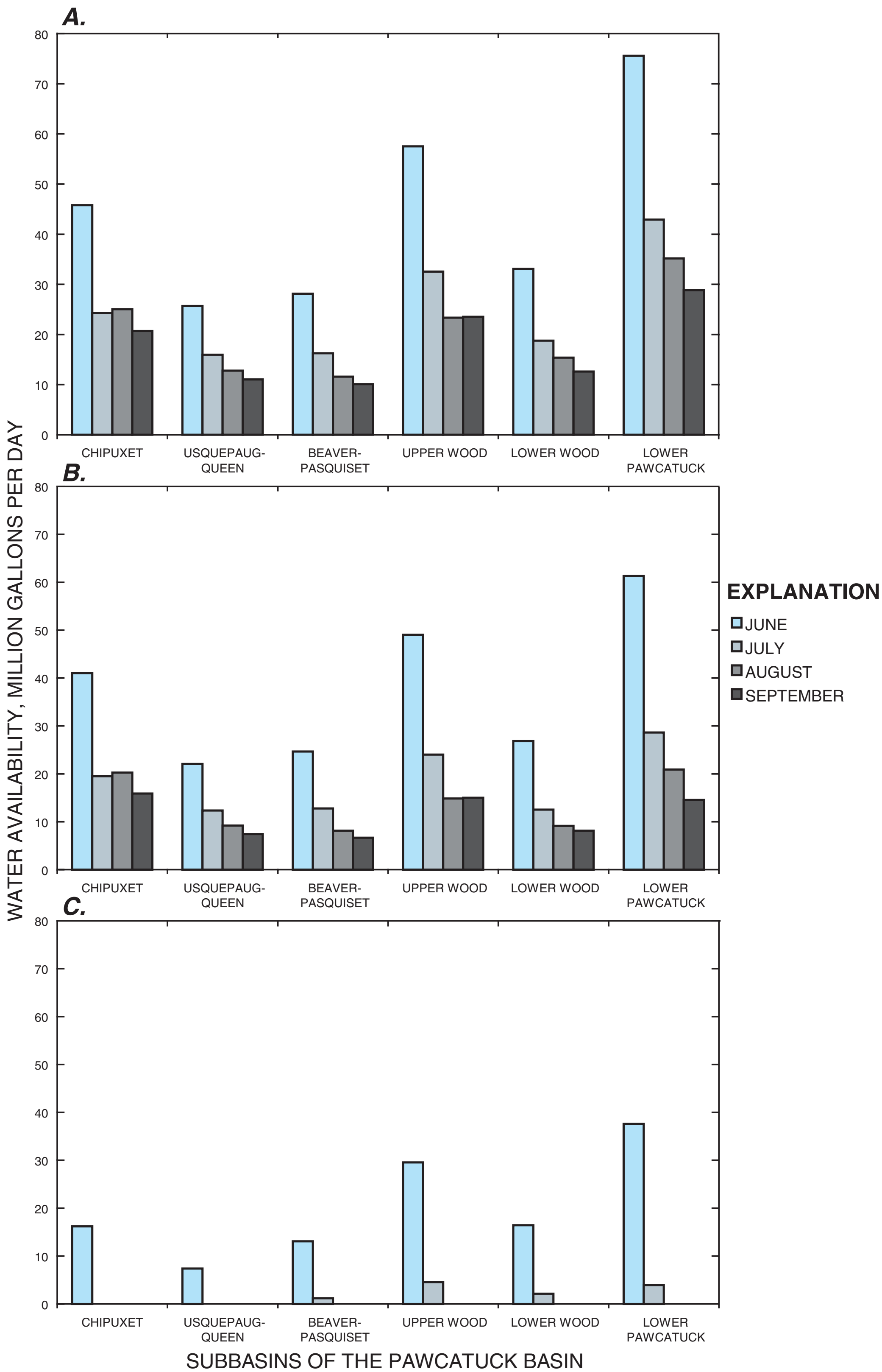



**Figure 16.** Estimated water availability for June, July, August, and September for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, based on the *A*, 50th percentile; *B*, 50th percentile minus the 7-day, 10-year flow criteria; and *C*, 50th percentile minus the Aquatic Base Flow criteria.

**Table 22.** Average water withdrawals for June, July, August, and September in the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, 1995–99.

[Mgal/d, million gallons per day]

| Subbasins | Average water withdrawals 1995–99 (Mgal/d) | | | |
|---|---|---|---|---|
| | June | July | August | September |
| Chipuxet subbasin | 4.976 | 6.120 | 5.972 | 4.141 |
| Usquepaug–Queen subbasin | .833 | 1.144 | 1.421 | .521 |
| Beaver–Pasquiset subbasin | .542 | .695 | .831 | .388 |
| Upper Wood subbasin | .870 | 1.041 | 1.175 | .702 |
| Lower Wood subbasin | .932 | 1.155 | 1.353 | .709 |
| Lower Pawcatuck subbasin | 5.201 | 5.975 | 5.747 | 4.459 |
| Basin total | 13.35 | 16.13 | 16.50 | 10.92 |

**Table 23.** Summary of water withdrawals to availability ratios for June, July, August, and September in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[7Q10, 7-day, 10-year flow; ABF, Aquatic Base Flow; Mgal/d, million gallons per day; --, values at station less than zero and not used]

| Subbasins | Ratio for June, estimated gross yield (Mgal/d) | | | Ratio for June, estimated gross yield minus 7Q10 (Mgal/d) | | | Ratio for June, estimated yield minus ABF (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Chipuxet subbasin[1] | 0.072 | 0.109 | 0.151 | 0.077 | 0.121 | 0.177 | 0.126 | 0.307 | 1.528 |
| Usquepaug–Queen subbasin[2] | .019 | .032 | .040 | .020 | .038 | .048 | .031 | .113 | .305 |
| Beaver–Pasquiset subbasin[3] | .011 | .019 | .024 | .012 | .022 | .028 | .017 | .041 | .071 |
| Upper Wood subbasin[4] | .010 | .015 | .020 | .012 | .018 | .025 | .016 | .029 | .057 |
| Lower Wood subbasin[5] | .022 | .028 | .035 | .026 | .035 | .046 | .036 | .057 | .096 |
| Lower Pawcatuck subbasin[5] | .054 | .069 | .086 | .063 | .085 | .113 | .089 | .138 | .234 |
| Basin ratios | 0.035 | 0.050 | 0.065 | 0.039 | 0.059 | 0.081 | 0.056 | 0.111 | 0.219 |

| Subbasin | Ratio for July, estimated gross yield (Mgal/d) | | | Ratio for July, estimated gross yield minus 7Q10 (Mgal/d) | | | Ratio for July, estimated yield minus ABF (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Chipuxet subbasin[1] | 0.140 | 0.252 | 0.337 | 0.158 | 0.314 | 0.458 | 0.438 | -- | -- |
| Usquepaug–Queen subbasin[2] | .054 | .072 | .105 | .066 | .093 | .158 | .423 | -- | -- |
| Beaver–Pasquiset subbasin[3] | .034 | .043 | .059 | .040 | .054 | .083 | .125 | 0.584 | -- |
| Upper Wood subbasin[4] | .025 | .032 | .044 | .032 | .043 | .069 | .079 | .229 | -- |
| Lower Wood subbasin[5] | .047 | .062 | .076 | .064 | .092 | .130 | .150 | .538 | -- |
| Lower Pawcatuck subbasin[5] | .108 | .139 | .173 | .145 | .209 | .294 | .340 | 1.532 | -- |
| Basin ratios | 0.078 | 0.107 | 0.141 | 0.098 | 0.147 | 0.220 | 0.266 | 1.368 | -- |

**Table 23.** Summary of water withdrawals to availability ratios for June, July, August, and September in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.—Continued

[7Q10, 7-day, 10-year flow; ABF, Aquatic Base Flow; Mgal/d, million gallons per day; --, values at station less than zero and not used]

| Subbasin | Ratio for August, estimated gross yield (Mgal/d) | | | Ratio for August, estimated gross yield minus 7Q10 (Mgal/d) | | | Ratio for August, estimated yield minus ABF (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Chipuxet subbasin[1] | 0.170 | 0.239 | 0.367 | 0.197 | 0.295 | 0.520 | 1.071 | -- | -- |
| Usquepaug–Queen subbasin[2] | .080 | .111 | .176 | .100 | .155 | .319 | -- | -- | -- |
| Beaver–Pasquiset subbasin[3] | .049 | .072 | .109 | .062 | .102 | .200 | .445 | -- | -- |
| Upper Wood subbasin[4] | .028 | .050 | .060 | .035 | .079 | .107 | .084 | -- | -- |
| Lower Wood subbasin[5] | .060 | .088 | .122 | .084 | .148 | .280 | .234 | -- | -- |
| Lower Pawcatuck subbasin[5] | .112 | .163 | .227 | .155 | .275 | .520 | .435 | -- | -- |
| Basin ratios | 0.089 | 0.134 | 0.188 | 0.114 | 0.200 | 0.352 | 0.409 | -- | -- |

| Subbasin | Ratio for September, estimated gross yield (Mgal/d) | | | Ratio for September, estimated gross yield minus 7Q10 (Mgal/d) | | | Ratio for September, estimated yield minus ABF (Mgal/d) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| Chipuxet subbasin[1] | 0.163 | 0.200 | 0.278 | 0.201 | 0.260 | 0.411 | -- | -- | -- |
| Usquepaug–Queen subbasin[2] | .032 | .047 | .069 | .041 | .070 | .131 | -- | -- | -- |
| Beaver–Pasquiset subbasin[3] | .028 | .038 | .057 | .037 | .058 | .115 | -- | -- | -- |
| Upper Wood subbasin[4] | .021 | .030 | .038 | .029 | .047 | .070 | 0.146 | -- | -- |
| Lower Wood subbasin[5] | .040 | .056 | .080 | .053 | .087 | .160 | .629 | -- | -- |
| Lower Pawcatuck subbasin[5] | .110 | .155 | .219 | .170 | .306 | .734 | 1.732 | -- | -- |
| Basin ratios | 0.074 | 0.102 | 0.142 | 0.101 | 0.161 | 0.287 | 1.282 | -- | -- |

[1]Estimated gross yields based on base flow from the Chipuxet stream-gaging station, 1974 through 2000.

[2]Estimated gross yields based on base flow from the Usquepaug stream-gaging station, 1975 through 2000.

[3]Estimated gross yields based on base flow from the Beaver stream-gaging station, 1975 through 2000.

[4]Estimated gross yields based on base flow from the Arcadia stream-gaging station, 1964 through 1981 and 1983 through 2000.

[5]Estimated gross yields based on base flow from the Wood River Junction stream-gaging station, 1941 through 2000.

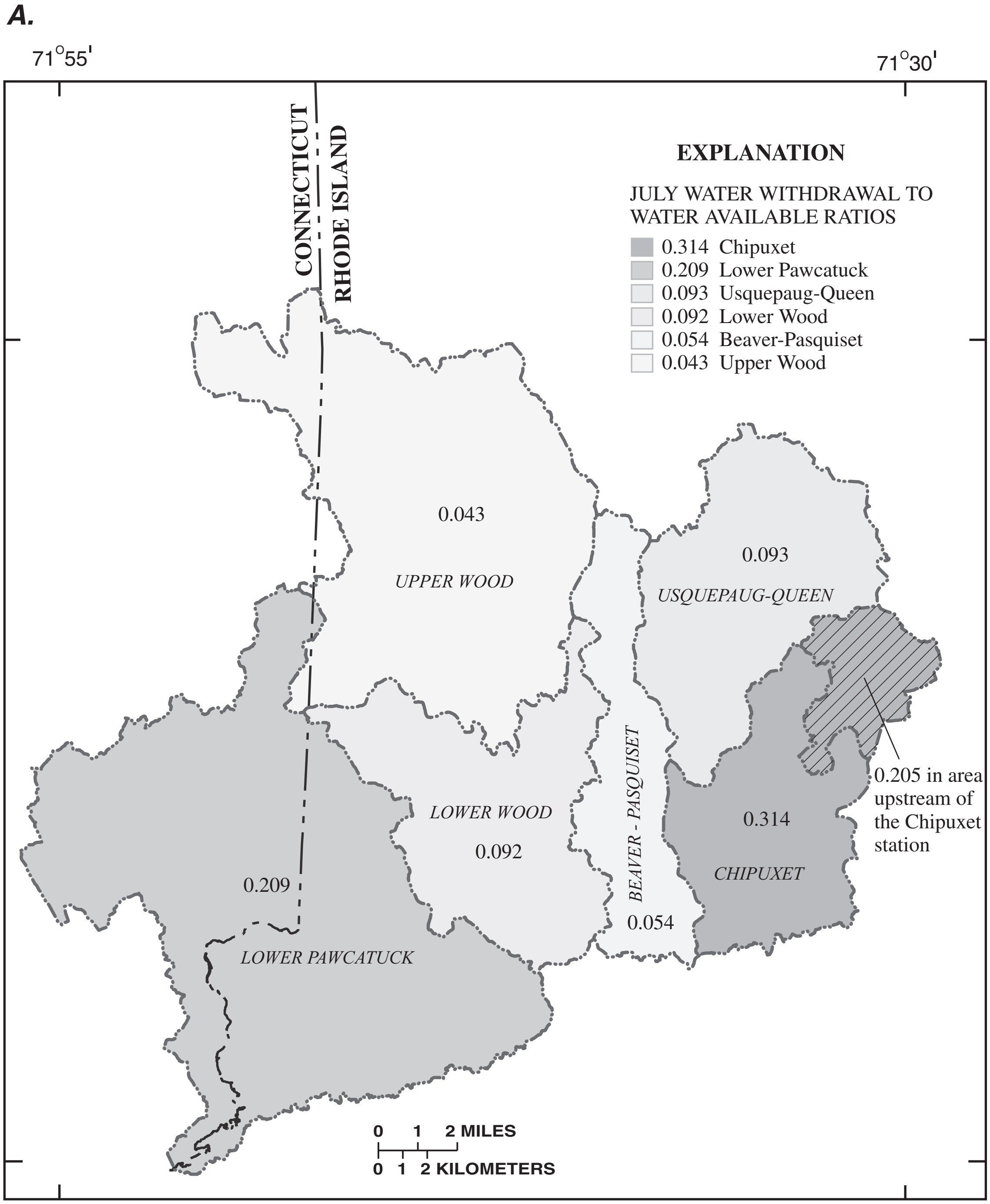



**Figure 17.** The water-withdrawal to water-availability ratio in *A*, July; *B*, August; and *C*, September for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, at the 50th percentile minus the 7-day, 10-year flow criteria.

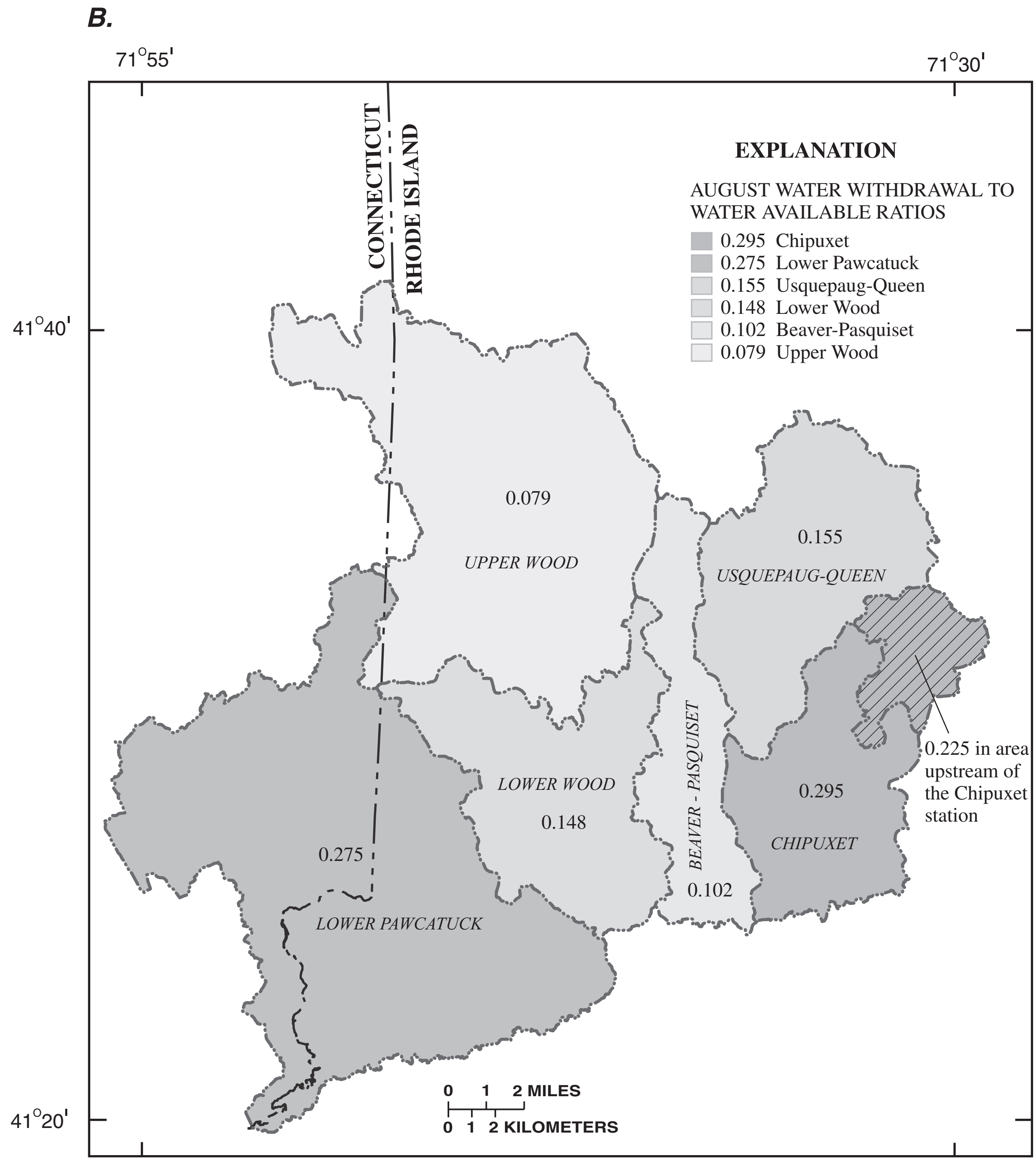



**Figure 17—Continued.** The water-withdrawal to water-availability ratio in *A*, July; *B*, August; and *C*, September for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, at the 50th percentile minus the 7-day, 10-year flow criteria.

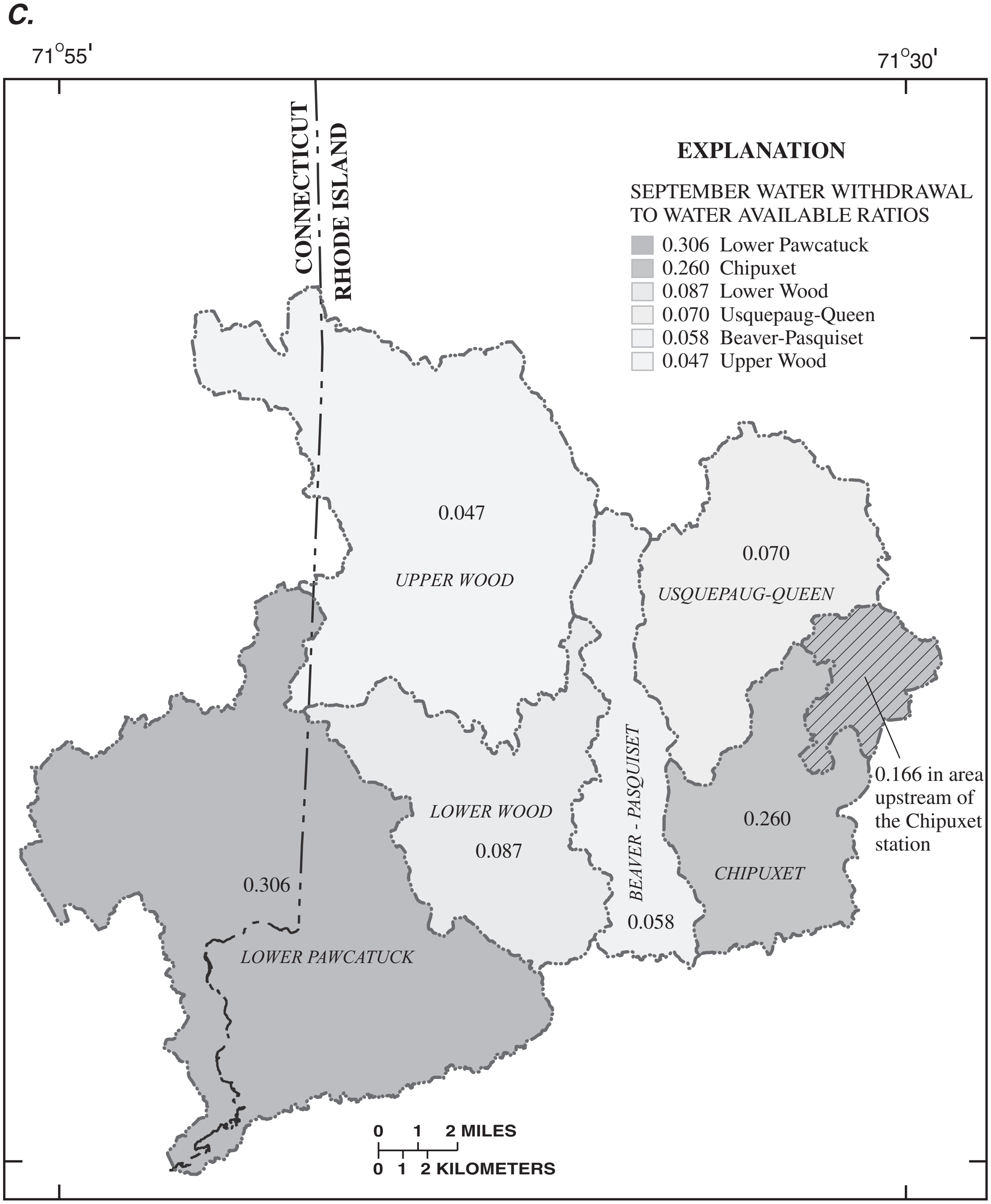



**Figure 17—Continued.** The water-withdrawal to water-availability ratio in *A*, July; *B*, August; and *C*, September for the subbasins in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut, at the 50th percentile minus the 7-day, 10-year flow criteria.

In the Lower Wood subbasin, the estimated water availability for the gross yield at the 50th percentile ranged from 9.012 Mgal/d in September to 23.63 Mgal/d in June for the contributions from sand and gravel deposits, and ranged from 3.604 Mgal/d in September to 9.448 Mgal/d in June for the contributions from till deposits (table 20). The water availability in the subbasin at the 50th percentile for the gross yield ranged from 12.62 Mgal/d in September to 33.08 Mgal/d in June, and by using the 7Q10 criteria, ranged from 8.130 Mgal/d in September to 26.83 Mgal/d in June (table 21).The average water withdrawals for the Lower Wood subbasin ranged from 0.709 Mgal/d in September to 1.353 Mgal/d in August for the study period (table 22). The results for the ratios for the gross-yield scenario at the 50th percentile ranged from 0.028 in June to 0.088 in August, and by using the 7Q10 criteria, the ratios ranged from 0.035 in June to 0.148 in August (table 23).

In the Lower Pawcatuck subbasin, the estimated water availability for the gross yield at the 50th percentile ranged from 16.36 Mgal/d in September to 42.88 Mgal/d in June for the contributions from sand and gravel deposits, and ranged from 12.47 Mgal/d in September to 32.70 Mgal/d in June for the contributions from till deposits (table 20). The water availability in the subbasin at the 50th percentile for the gross yield ranged from 28.83 Mgal/d in September to 75.58 Mgal/d in June, and by using the 7Q10 criteria, ranged from 14.56 Mgal/d in September to 61.31 Mgal/d in June (table 21).The average water withdrawals for the Lower Pawcatuck subbasin ranged from 4.459 Mgal/d in September to 5.975 Mgal/d in July for the study period (table 22). The results for the ratios for the gross-yield scenario at the 50th percentile ranged from 0.069 in June to 0.163 in August, and by using the 7Q10 criteria, the ratios ranged from 0.085 in June to 0.306 in September (table 23).

The Chipuxet subbasin resulted as the area where most of the withdrawals were present and where the water withdrawals were approaching or passing the estimated water available, resulting in higher ratios. Therefore, further analysis was conducted on the water withdrawals and availability in the area upstream of the Chipuxet stream-gaging station. The summer water withdrawals for the study period in this area ranged from 0.534 Mgal/d in September to 0.924 Mgal/d in August (table 24). The results for the ratios for the gross-yield scenario at the 50th percentile ranged from 0.061 in June to 0.182 in August, and by using the 7Q10 criteria, the ratios ranged from 0.068 in June to 0.225 in August (table 24).

## Streamflow Depletion

The streamflow-depletion program (STRMDEPL) developed by Barlow (2000) is used to examine the depletion of the streams from wells near the streams. The program is based on methods and equations from Jenkins (1968); the program is for wells where the sediments along the streambank are impervious. The Jenkins method was used to assess what effect the Kingston Water District wells 1 and 2 had on the Chipuxet River, and to assess the effect the Westerly Water Department withdrawals at well field 1, well field 2, and well 3 had on the Pawcatuck River. The depletions of Chipuxet River flows by Kingston Water District wells 1 and 2 were estimated with STRMDEPL by using daily withdrawals from the Chipuxet aquifer for January 1, 1995, through December 31, 1999. The depletions of the Pawcatuck River by the Westerly Water Department's well fields 1 and 2 and well 3 were also estimated by using daily withdrawals for October 1, 1997, through September 30, 1999 (table 25). The details of the well distances to the streams, transmissivities, diffusivities, and comparisons to the data for the station near the well are presented in table 25. The streamflow depletions for Kingston well 1 and 2, Westerly well fields 1 and 2, and well 3 were approximately 96, 98, 101, 98, and 100 percent of the average daily water withdrawals for the periods specified.

Because the summer of 1999 was drier than other summers during the study period, further analysis was completed for the streamflow depletions of the Kingston and Westerly withdrawal wells. In July of 1999, streamflow depletions for Kingston well 1 and 2, Westerly well fields 1 and 2, and well 3 were approximately 101, 99, 101, 98, and 99 percent of the average daily water withdrawals for the periods specified (table 26). Information and results for the well withdrawals, streamflow depletion for June, July, August, and September are presented in table 26. For comparison to the withdrawals and streamflow depletions, streamflows at the Chipuxet and Westerly stream-gaging stations were calculated during 1999 and are presented in table 27. In addition, a simulation was done to assess the streamflow depletion from continuous water withdrawals. In the simulation, public well and well fields were simulated at a constant pumping rate, based on the 1999 summer average for each withdrawal, over a period of 180 days. As a result, the percentages of streamflow depletion were 86 and 95 after 30 days of continuous pumping at Kingston wells 1 and 2, respectively, as shown in figure 18 and table 28. The percentages of streamflow depletion were 93, 96, and 98 percent after 30 days of pumping at Westerly well fields 1 and 2, and well 3, respectively, as shown in figure 19 and table 28.

## Water Budget

The Pawcatuck Basin water budget encompasses the hydrologic cycle and the water-use components, inflow and outflow to the system. For a water budget, inflow minus outflow equals the change in storage in the basin. For this report, long-term water budget was calculated where inflow equals outflow in the system. The change in water storage from surface-water bodies and from ground-water aquifers is considered to be negligible in this water budget. Inflows to the basin include precipitation, streamflow from upstream subbasins, ground-water inflow, and return flow (septic systems, RIPDES, and wastewater-treatment facilities). Outflows from the basin include evapotranspiration, streamflow out of the subbasins, water withdrawals (public supplies and self-supplied domestic, commercial, industrial, and agricultural), and ground-water underflow. The water budget components are summarized in table 29.

**Table 24.** Monthly water withdrawals and withdrawal to availability ratios for the Chipuxet stream-gaging station in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[7Q10, 7-day, 10-year flow; ABF, Aquatic Base Flow, based on the median of the August monthly means; Mgal/d, Million gallons per day; --, values at station less than zero and not used]

| Month | Withdrawals upstream of Chipuxet station (Mgal/d) | Ratio of water withdrawals to availability at the Chipuxet stream-gaging station | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Estimated gross yield | | | Estimated gross yield minus 7Q10 | | | Estimated gross yield minus ABF | | |
| | | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile | 75th percentile | 50th percentile | 25th percentile |
| June | 0.569 | 0.041 | 0.061 | 0.085 | 0.044 | 0.068 | 0.100 | 0.071 | 0.173 | 0.862 |
| July | .808 | .091 | .164 | .220 | .103 | .205 | .298 | .286 | -- | -- |
| August | .924 | .130 | .182 | .280 | .150 | .225 | .397 | .818 | -- | -- |
| September | .534 | .104 | .127 | .177 | .128 | .166 | .261 | -- | -- | -- |

**Table 25.** Average distance, transmissivity, diffusivity, pumping rate, streamflow-depletion rates, and streamflow of rivers from the Kingston and Westerly public-supply wells and well fields used in Jenkins analysis in the Pawcatuck Basin in southern Rhode Island.

[**Reference letter:** Identifier used in figure 4. To convert to million gallons per day, multiply cubic feet per second by 0.646577. d, day; ft, foot; $ft^2/d$, square foot per day; $ft^2/s$, square foot per second; $ft^3/s$, cubic foot per second; <, actual value is less than value shown]

| Selected public-water supplier | Public-supply wells and (or) well fields | Reference letter | Average distance to river (ft) | Average transmissivity ($ft^2/d$) | Diffusivity ($ft^2/s$) | Average pumping rate ($ft^3/s$) | Average streamflow-depletion rate ($ft^3/s$) | Average streamflow ($ft^3/s$) | Lag time (d) |
|---|---|---|---|---|---|---|---|---|---|
| Kingston Water District[1] | Well 1 | A | 370 | 21,200 | 0.8681 | 0.2127 | 0.2044 | 21.44 | <1 |
| | Well 2 | B | 120 | 21,200 | .8681 | .4748 | .4738 | 21.44 | <1 |
| Westerly Water Department[2] | Well field 1 | -- | 256 | 40,000 | 1.6543 | 1.3530 | 1.3674 | 612.04 | <1 |
| | Well 1A | M | 396 | | | | | | |
| | Well 1B | N | 133 | | | | | | |
| | Well 1D | O | 240 | | | | | | |
| | Well field 2 | -- | 161 | 40,000 | 1.6543 | 1.668 | 1.668 | 612.04 | <1 |
| | Well 2A | P | 215 | | | | | | |
| | Well 2B | Q | 164 | | | | | | |
| | Well 2D | R | 105 | | | | | | |
| | Well 3 | S | 83 | 40,000 | 1.6543 | .7057 | .7070 | 612.04 | <1 |

[1]Average transmissivity from Johnston and Dickerman (1985). Average streamflow depletion from daily withdrawals from Kingston wells near the Chipuxet River, 1995 through 1999.

[2]Average transmissivity from Gonthier and others (1974). Average streamflow depletion from daily withdrawals from Westerly wells near the Pawcatuck River, November 1997 through September 1999.

**Table 26.** Average pumping rate and streamflow depletion from selected Kingston and Westerly public-supply wells used in Jenkins analysis during June, July, August, and September of 1999 in the Pawcatuck Basin, southern Rhode Island.

[Jenkins analysis from Jenkins (1968). Mgal/d, million gallons per day]

| Selected public wells and well fields | June 1999 (Mgal/d) | | July 1999 (Mgal/d) | | August 1999 (Mgal/d) | | September 1999 (Mgal/d) | |
|---|---|---|---|---|---|---|---|---|
| | Average pumping rate | Average streamflow-depletion rate | Average pumping rate | Average streamflow-depletion rate | Average pumping rate | Average streamflow-depletion rate | Average pumping rate | Average streamflow-depletion rate |
| Kingston Water District | | | | | | | | |
| Well 1 | 0.239 | 0.230 | 0.187 | 0.188 | 0.187 | 0.188 | 0.123 | 0.134 |
| Well 2 | .385 | .374 | .391 | .385 | .314 | .317 | .295 | .296 |
| Total | 0.624 | 0.604 | 0.578 | 0.574 | 0.501 | 0.506 | 0.419 | 0.431 |
| Westerly Water Department | | | | | | | | |
| Well field 1 | 1.265 | 1.239 | 1.071 | 1.078 | 1.028 | 1.034 | 0.961 | 0.978 |
| Well field 2 | 1.468 | 1.430 | 1.641 | 1.606 | 1.138 | 1.155 | 1.053 | 1.042 |
| Well 3 | .535 | .533 | .541 | .537 | .557 | .556 | .379 | .387 |
| Total | 3.268 | 3.201 | 3.252 | 3.222 | 2.723 | 2.745 | 2.393 | 2.407 |

**Table 27.** Average streamflow at the Chipuxet River and Pawcatuck River stream-gaging stations during June, July, August, and September of 1999 in the Pawcatuck Basin, southern Rhode Island.

[Mgal/d, million gallons per day]

| Station | Average streamflow (Mgal/d) | | | |
|---|---|---|---|---|
| | June 1999 | July 1999 | August 1999 | September 1999 |
| Chipuxet River at West Kingston, RI | 7.27 | 2.84 | 1.61 | 3.94 |
| Pawcatuck River at Westerly, RI | 148.1 | 71.83 | 46.47 | 161.5 |

The average precipitation at Kingston, RI, was calculated for the period of record reported in the water budget at the index stations. For the Chipuxet subbasin, an average precipitation of 51.26 in/yr for 1974 through 2000 was applied to the subbasin by using 2.442 Mgal/d/mi$^2$. For the Usquepaug–Queen and Beaver–Pasquiset subbasins, an average precipitation of 51.61 in/yr for 1975 through 2000 was applied to the subbasin by using 2.458 Mgal/d/mi$^2$. For the Upper Wood subbasin, an average precipitation of 50.34 in/yr for 1964 through 1981 and 1983 through 2000 was applied to the subbasin by using 2.399 Mgal/d/mi$^2$. For the Lower Wood and Lower Pawcatuck subbasins, an average precipitation of 48.08 in/yr for 1941 through 2000 was applied to the subbasins by using 2.287 Mgal/d/mi$^2$. The Beaver–Pasquiset, Lower Wood, and Lower Pawcatuck subbasins have surface-water inflow from subbasins upstream. Estimating ground-water inflow was considered negligible for this study because of data availability. Return flow includes the average disposal of water from septic systems from 1995 through 1999, RIPDES, and wastewater-treatment facilities in the subbasins of the Pawcatuck Basin. Evapotranspiration was estimated based on the difference between the precipitation and outflow at the confluence, which was based on the mean annual flow at the index stream-gaging station. The outflow of streamflow from each subbasin was estimated by using the sum of the inflows minus the withdrawals minus evapotranspiration.

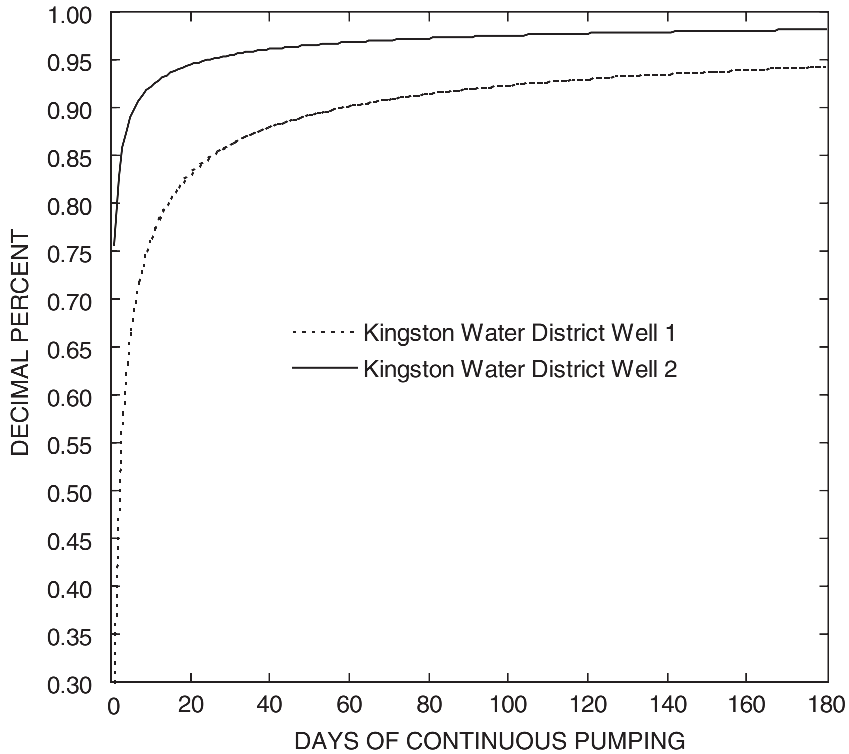



**Figure 18.** Decimal percentage of streamflow depletion simulation during 180 days of continuous pumping for Kingston Water District wells 1 and 2, Pawcatuck Basin, southern Rhode Island.

**Table 28.** Pumping rate for 180 days and percent streamflow depletion divided by pumping rate from selected public-supply withdrawal wells for the Kingston Water District and Westerly Water Department used in Jenkins analysis in 1999 in the Pawcatuck Basin, southern Rhode Island.

[Jenkins analysis from Jenkins (1968). **Pumping rate:** Based on the average daily pumping rate for June–September 1999. $ft^3/s$, cubic foot per second; Mgal/d, million gallons per day]

| Selected wells and well fields | Pumping rate | | Percent streamflow depletion of the water withdrawals | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mgal/d | $ft^3/s$ | 10 days | 20 days | 30 days | 40 days | 50 days | 60 days | 70 days | 80 days | 90 days |
| Kingston Water District | | | | | | | | | | | |
| Well 1 | 0.184 | 0.285 | 76 | 83 | 86 | 88 | 89 | 90 | 91 | 91 | 92 |
| Well 2 | .347 | .536 | 92 | 94 | 95 | 96 | 97 | 97 | 97 | 97 | 97 |
| Westerly Water Department | | | | | | | | | | | |
| well field 1 | 1.082 | 1.673 | 88 | 91 | 93 | 94 | 95 | 95 | 95 | 96 | 96 |
| well field 2 | 1.328 | 2.054 | 92 | 95 | 96 | 96 | 97 | 97 | 97 | 97 | 97 |
| Well 3 | .505 | .781 | 96 | 97 | 98 | 98 | 98 | 98 | 99 | 99 | 99 |

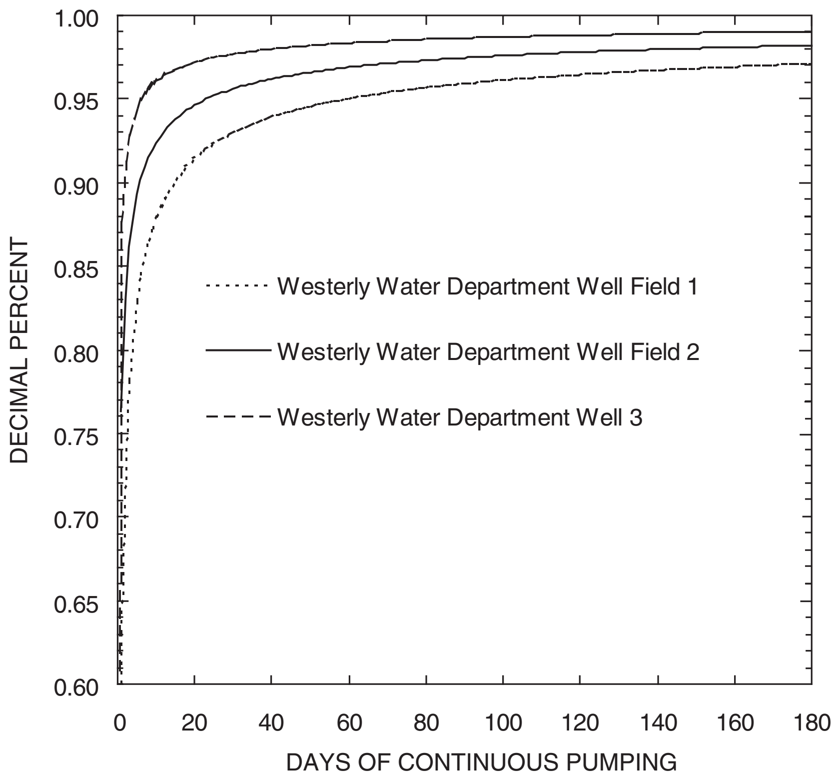



**Figure 19.** Decimal percentage of streamflow depletion simulation during 180 days of continuous pumping for Westerly Water Department well fields 1 and 2, and well 3, Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

For the water budget, it was assumed that inflow equals outflow for the subbasins. The total water budget for the Chipuxet subbasin was 90.64 Mgal/d. The estimated percentages of inflows from precipitation and water return flow were 99 and 1 percent, and the estimated percentages of outflows from evapotranspiration, streamflow, and water withdrawals were 44, 52, and 4 percent in the Chipuxet subbasin, respectively. The total water budget for the Usquepaug–Queen subbasin was 89.06 Mgal/d. The estimated percentages of inflows from precipitation and water return flow were 99 and 1 percent, and the estimated percentages of outflows from evapotranspiration, streamflow, and water withdrawals were 44, 55, and 1 percent in the Usquepaug–Queen subbasin, respectively. The total water budget for the Beaver–Pasquiset subbasin was 152.1 Mgal/d. The estimated percentages of inflows from precipitation, streamflow from upland subbasins, and water return flow were 36, 63, and 1 percent, and the estimated percentages of outflows from evapotranspiration, streamflow, and water withdrawals were 13, 86, and 1 percent in the Beaver–Pasquiset subbasin, respectively. The total water budget for the Upper Wood subbasin was 175.5 Mgal/d. The estimated percentages of inflows from precipitation and water return flow were 99 and 1 percent, and the estimated percentages of outflows from evapotranspiration, streamflow, and estimated percentages of water withdrawals were 41, 58, and 1 percent in the Upper Wood subbasin, respectively. The total water budget for the Lower Wood subbasin was 317.9 Mgal/d. The estimated percentages of inflows from precipitation, streamflow from upland subbasins, and water return flow were 26, 73, and 1 percent, and the estimated percentages of outflows from evapotranspiration, streamflow, and water withdrawals were 12, 88, and 0 percent in the Lower Wood subbasin, respectively. The total water budget for the Lower Pawcatuck subbasin was 507.3 Mgal/d. The estimated percentages of inflows from precipitation, streamflow from upland subbasins, and water return flow were 44, 55, and 1 percent, and the estimated percentages of outflows from evapotranspiration, streamflow, and estimated percentages of water withdrawals were 20, 79, and 1 percent in the Lower Pawcatuck subbasin, respectively.

**Table 29.** Average water budget by subbasin for the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[RIPDES, Rhode Island Pollution Discharge Elimination System; in/yr, inches per year; Mgal/d, million gallons per day; Mgal/d/mi$^2$, million gallons per day per square mile; mi$^2$, square miles; --, not applicable]

| Water-budget component | Rate of flow (Mgal/d) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Chipuxet subbasin | Usquepaug–Queen subbasin | Beaver–Pasquiset subbasin | Upper Wood subbasin | Lower Wood subbasin | Lower Pawcatuck subbasin | Pawcatuck Basin |
| **Estimated Inflow** | | | | | | | |
| Precipitation | [1]90.09 | [2]88.74 | [2]55.31 | [3]175.0 | [4]83.26 | [4]222.8 | 715.2 |
| Streamflow from upstream subbasins | -- | -- | 96.18 | -- | 233.5 | 279.8 | -- |
| Ground-water inflow | -- | -- | -- | -- | -- | -- | -- |
| Return flow[5] | .549 | .316 | .599 | .542 | 1.109 | 4.740 | 7.855 |
| Total inflow | 90.64 | 89.06 | 152.1 | 175.5 | 317.9 | 507.3 | 723.1 |
| **Estimated Outflow** | | | | | | | |
| Evapotranspiration[6] | [7]39.51 | [8]39.13 | [9]20.43 | [10]72.46 | [11]37.27 | [11]99.70 | 308.5 |
| Streamflow[12] | 46.92 | 49.26 | 131.2 | 102.3 | 279.8 | 403.3 | 403.3 |
| Water withdrawals[13] | 4.212 | .674 | .463 | .779 | .819 | 4.303 | 11.25 |
| Ground-water underflow | -- | -- | -- | -- | -- | -- | -- |
| Total outflow | 90.64 | 89.06 | 152.1 | 175.5 | 317.9 | 507.3 | 723.1 |
| **Streamflow and Drainage Area** | | | | | | | |
| Streamflow per square mile (Mgal/d/mi$^2$) | 1.270 | 1.364 | 1.374 | 1.402 | 1.365 | 1.334 | 1.334 |
| Total drainage area at outlet (mi$^2$) | 36.93 | 36.10 | 95.50 | 72.98 | 204.9 | 302.4 | 302.4 |

[1] Based on average precipitation (51.26 in/yr) at Kingston, RI, 1974–2000.

[2] Based on average precipitation (51.61 in/yr) at Kingston, RI, 1975–2000.

[3] Based on average precipitation (50.34 in/yr) at Kingston, RI, 1964–81 and 1983–2000.

[4] Based on average precipitation (48.02 in/yr) at Kingston, RI, 1941–2000.

[5] Return flow based on the total return flow from septic, RIPDES, and wastewater-treatment facilities, in the subbasins of the Pawcatuck Basin, 1995–99.

[6] Evapotranspiration based on the difference between the average precipitation at Kingston, RI, and average monthly flow at the index stream-gaging station for the subbasin.

[7] Based on average monthly flow per unit area (1.371 Mgal/d/mi$^2$) at the stream-gaging station Chipuxet River at West Kingston, RI, 1974–2000.

[8] Based on average monthly flow per unit area (1.374 Mgal/d/mi$^2$) at the stream-gaging station Usquepaug River near Usquepaug, RI, 1975–2000.

[9] Based on average monthly flow per unit area (1.550 Mgal/d/mi$^2$) at the stream-gaging station Beaver River near Usquepaug, RI, 1975–2000.

[10] Based on average monthly flow per unit area (1.405 Mgal/d/mi$^2$) at the stream-gaging station Wood River near Arcadia, RI, 1964–81 and 1983–2000.

[11] Based on average monthly flow per unit area (1.263 Mgal/d/mi$^2$) at the stream-gaging station Pawcatuck River at Wood River Junction, RI, 1941–2000.

[12] Based on the sum of the inflows minus withdrawals and evapotranspiration.

[13] Water-withdrawal types include domestic, commercial, industrial, and agricultural withdrawals by users served by public- and self-supplied water in the subbasins of the Pawcatuck Basin, 1995–99.

# Summary

The Pawcatuck Basin (302 square miles) is in southern Rhode Island (245.3 square miles) and southeastern Connecticut (57.12 square miles). In 1988, the Pawcatuck Basin was defined as a sole-source aquifer for 14 towns in southern Rhode Island and 4 towns in southeastern Connecticut for public-water suppliers and self-supplied populations.

From the 1990 population census to the 2000 population census, population growth of southern Rhode Island ranged from a 6.3 percent increase in Westerly to a 35 percent increase in Richmond. During the study period, from 1995 through 1999, the estimated population growth was highest in this same region, ranging from a 3-percent increase in Hopkinton and Westerly to a 10-percent increase in Richmond. Town populations also increased in the basin, and withdrawals increased from the ground-water system (sand and gravel deposits, ground-water reservoirs, and till deposits). During the drought of 1999, a rain deficiency resulted in ground-water levels and streamflows dropping below the long-term averages throughout Rhode Island. Consequently, the State became increasingly concerned about water availability, and further investigation was needed to assess water use and availability throughout Rhode Island.

The U.S. Geological Survey, in cooperation with the Rhode Island Water Resources Board, began a series of water-use and availability projects to better understand the relations between the water-use components and the components of the hydrologic cycle (predominantly surface and ground water) during periods of little to no recharge. One of the first areas of concern in this assessment was the Pawcatuck Basin because ground water is the principal water source for public suppliers and domestic users in the basin.

This report assesses water use and availability in the Pawcatuck Basin and in its six ground-water subbasins for periods of little to no recharge. Water-use data were collected by ground-water subbasins for the towns and systems (supply and disposal) in the basin. The New England Water-Use Data System was used to organize and retrieve the water withdrawals and discharges for different kinds of water use during the study period. The report presents the water availability calculated for the six subbasins by a method of determining ground-water discharge during streamflow-recession periods in the summer. To assess the streamflow and ground-water interactions, a streamflow-depletion program was run for five of the public-supply wells and well fields that are near the streams. A basin water budget is also presented that summarizes the components of the hydrologic cycle on the basis of the long-term period of record and selected water-use components for the study period.

The five major water suppliers in the basin withdrew an average of 6.768 million gallons per day (Mgal/d) from the aquifers in the subbasins during the study period. The estimated water withdrawals from minor suppliers during the study period were 0.099 Mgal/d. Self-supplied domestic, industrial, commercial, and agricultural withdrawals from the basin averaged 4.386 Mgal/d. Public-supply and self-supplied domestic, commercial, and industrial withdrawals in the basin were from ground water. Agricultural withdrawals for irrigation were assumed to be from surface water and ground water, based on previously published studies. Water use in the basin averaged 7.401 Mgal/d from 1995 through 1999. The average return flow in the basin was 7.855 Mgal/d, which includes effluent from permitted facilities and self-disposed water users.

The computerized PART program, a hydrograph-separation application, was used for data at selected index stream-gaging stations to determine water availability based on the 75th, 50th, and 25th percentiles of the total base flow, the base flow minus the 7-day, 10-year low-flow (7Q10) criteria at the index station, and the base flow minus the Aquatic Base Flow (ABF) criteria at the index station. Selected index stations for the Chipuxet subbasin, Usquepaug–Queen subbasin, Beaver–Pasquiset subbasin, and Upper Wood subbasin were the Chipuxet River at West Kingston (station 01117350), Usquepaug River near Usquepaug (station 01117420), Beaver River near Usquepaug (station 01117468), and Wood River near Arcadia (station 01117800), respectively. The Pawcatuck River at Wood River Junction stream-gaging station (01117500) was used as the index station for the Lower Wood and Lower Pawcatuck subbasins. During the summer, portions of the ground water drains out of the Pawcatuck Basin in the Chipuxet and Usquepaug–Queen subbasins. The differences in the surface and subsurface drainage areas in the summer have been applied to the water availability calculated at the stream-gaging stations and subbasins.

Contributions of base flow from surficial deposits, till, and stratified sand and gravel for the index stations are based on previous work by the U.S. Geological Survey. The base-flow contributions from sand and gravel deposits at the index stations were 67 percent at the Chipuxet stream-gaging station, 71 percent at the Usquepaug and Wood River Junction stream-gaging stations, 52 percent at the Beaver stream-gaging station, and 57 percent at the Arcadia stream-gaging station. The base-flow contributions from till deposits at the index stations were 33 percent at the Chipuxet stream-gaging station, 29 percent at the Usquepaug and Wood River Junction stream-gaging stations, 48 percent at the Beaver stream-gaging station, and 43 percent at the Arcadia stream-gaging station. The two contributions for June, July, August, and September were applied to the percentage of surficial deposits at each index station, converted into a per unit area rate for the till areas and sand and gravel areas in the subbasins. The scenarios used to estimate the gross yield of base flow, as well as subtracting out the two low-flow criteria resulted in various water-availability values at each index station, which were then present in the subbasin after applying the per unit area rates from the index station. The results at the Chipuxet and Arcadia stream-gaging station were lowest in September at the 75th and 25th percentiles, while August flows were lowest for the summer at the 50th percentile. For the other three index stations, September flows were the lowest for the summer. Water-availability estimates and water-withdrawal to availability ratios were calculated for each subbasin. The cumulative withdrawals from upstream subbasins have not been accounted for in the water-availability calculations for the downstream subbasins.

Because water withdrawals and use are greater during the summer than other times in the year, water availability in June, July, August, and September was assessed and compared to the water withdrawals in the basin and subbasins. The average water withdrawals for the Pawcatuck Basin ranged from 10.92 Mgal/d in September to 16.50 Mgal/d in August for the study period. The water availability in the basin at the 50th percentile for the gross yield ranged from 106.8 Mgal/d in September to 265.8 Mgal/d in June, and by using the 7Q10 scenario, water availability in the basin ranged from 67.66 Mgal/d in September to 224.9 Mgal/d in June.

The water withdrawals to availability ratios were calculated for June, July, August, and September as an indicator of net availability of water in the basin and subbasins. The closer the ratio is to one, the closer the withdrawals are to the estimated water available. The ratios were calculated by using the water-availability scenarios at the 75th, 50th, and 25th percentiles for the subbasins and were based on total water available from base-flow contributions from till deposits and sand and gravel deposits in the subbasins.

The withdrawals in August for the study period were higher than in the other summer months, and the water withdrawal-to-availability ratio was closer to one in the Pawcatuck Basin. The ratio at the 50th percentile for the basin was 0.134 by using the gross-yield scenario, and 0.200 for the base flow minus the 7Q10 criteria at the index station. The Chipuxet subbasin had the highest water withdrawal-to-availability ratios in all of the selected scenarios and months. The results in the subbasin for the ratios in July at the 50th percentile were 0.252 for the gross-yield scenario and 0.314 for the base flow minus the 7Q10 flow at the index station.

The Chipuxet subbasin resulted as the area where most of the withdrawals were present and where the water withdrawals were approaching or passing the estimated water available, resulting in higher ratios. Therefore, further analysis was conducted on the water withdrawals and availability in the area upstream of the Chipuxet stream-gaging station. The summer water withdrawals for the study period in this area ranged from 0.534 Mgal/d in September to 0.924 Mgal/d in August. The results for the ratios in August at the 50th percentile were 0.182 for the gross yield scenario and 0.225 for the base flow minus the 7Q10 criteria at the station.

The depletions of the Chipuxet River flows by Kingston Water District wells 1 and 2 were estimated with the program STRMDEPL by using daily withdrawals from the Chipuxet aquifer for the period January 1, 1995 through December 31, 1999. The depletions of the Pawcatuck River by the Westerly Water Department’s well field 1 and 2 and well 3 were also estimated by using daily withdrawals for the period October 1, 1997 through September 30, 1999. The streamflow depletions for Kingston well 1 and 2, Westerly well fields 1 and 2, and well 3 were approximately 96, 98, 101, 98, and 100 percent, respectively, of the average daily water withdrawals for the periods specified. To present the effects of streamflow depletion from continuous water withdrawals, public well and well fields were simulated at a constant pumping rate, based on the 1999 summer average for each withdrawal, over a period of 180 days. As a result, the streamflow depletion was 86, 95, 93, 96, and 98 percent at 30 days for the Kingston well 1 and 2, Westerly well fields 1 and 2, and well 3, respectively.

A long-term hydrologic budget was calculated for the Pawcatuck Basin to identify and assess the basin and subbasin inflow and outflows. The water withdrawals and return flows used in the budget were from the period of study, 1995 through 1999. For the hydrologic budget, it was assumed that inflow equals outflow, which resulted in 723.1 Mgal/d in the basin. The estimated percentages of inflow from precipitation and return flow were 99 and 1 percent in the basin, respectively. The estimated percentages of outflow from evapotranspiration, streamflow, and water withdrawals were 43, 56, and 1 percent in the basin, respectively.

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# Glossary

**7-day, 10-year flow (7Q10):** The discharge at the 10-year recurrence interval taken from a frequency curve of annual values of the lowest mean discharge for 7 consecutive days (the 7-day low flow)

**Aquatic Base Flow (ABF):** Median flow during the month of August established by the U.S. Fish and Wildlife Service and considered adequate flow to protect indigenous aquatic fauna throughout the year. It can be calculated as long as there is: "USGS gaging data for at least 25 years of unregulated flow, and the drainage area at the stream-gaging station is at least 50 square miles" (U.S. Fish and Wildlife Service, 1981).

**Base flow:** Streamflow from ground-water discharge.

**Commercial water use:** Water used for transportation; wholesale trade; retail trade; finance, insurance, and real estate; services; and public administration (the two-digit Standard Industrial Classification codes are in the range of 40–97). The water can be from public or self supply.

**Consumptive use:** Water that is removed from the environment through evaporation, transpiration, production, or consumed by humans or livestock.

**Conveyance:** Movement of water from one point to another, for example water withdrawals, water distributions, and wastewater collection.

**Distribution:** The conveyance of water from a point of withdrawal or purification system to a user or other water customer.

**Domestic water use:** Water for household purposes, such as drinking, food preparation, bathing, washing, clothes and dishes, flushing toilets, and watering lawns and gardens. Households include single and multi-family dwellings. Also called residential water use. The water may be obtained from a public water supply or may be self supplied.

**Industrial water use:** Water used for food, tobacco, textile mill products, apparel, lumber and wood; furniture; paper; printing; chemicals; petroleum; rubber; leather; stone, clay, glass, and concrete; primary metal; fabricated metal; machinery; electrical equipment; transportation equipment; instruments; and jewelry, precious metals; where the two-digit Standard Industrial Classification codes range is 20–39. The water may be obtained from a public water supply or may be self supplied.

**Interbasin transfers:** Conveyance of water across a drainage or river-basin divide.

**Interconnections:** Links between water-supply districts to convey water. These connections can be for wholesale distributions or used as water-supply backups.

**Irrigation water use:** The artificial application of water on lands to assist in the growth of crops or pasture including in greenhouses. Irrigation water use may also include application of water to maintain vegetative growth in recreational lands such as parks and golf courses, including water used for frost and freeze protection of crops.

**Major water supplier:** A public or private system that withdraws and distributes water to customers or other suppliers for use.

**Major user:** In Rhode Island, it is defined as a customer that uses more than 3 million gallons of water per year.

**Minor Civil Division (MCD):** A term used by the U.S. Census Bureau, general equivalent to a city or town.

**Minor water suppliers:** Water withdrawn to supply a site-specific public population, for example, nursing homes, condominium complexes, and mobile home parks.

**Non-account water use:** The difference between the metered (or reported) supply and the metered (or reported) use for a specific period of time, which includes water used for fire fighting. It comprises authorized and unauthorized water uses.

**Outfall:** Refers to the outlet or structure through which effluent is finally discharged into the environment.

**Per capita water use:** The average volume of water used per person during a standard time period, generally per day.

**PART:** A computer program developed by A.T. Rutledge (1993; 1998) to determine the mean rate of ground-water discharge.

**Public wastewater system:** Wastewater collected from users or groups of users, conveyed to a wastewater-treatment plant, and then released as return flow into the hydrologic environment or sent back to users as reclaimed wastewater.

**Public water system:** Water withdrawn by public and private water systems, and then delivered to users or groups of users. Public water systems provide water for a variety of uses, such as domestic, commercial, industrial, agricultural, and public water use.

**Public water use:** Water supplied from a public water system and used for fire fighting, street washing, and municipal parks and swimming pools.

**Public-disposed water:** Water return flow from public and private wastewater-collection systems.

**Public-supplied water:** Water distributed to domestic, industrial, commercial, agricultural, or other customers by a public or private water-supply system.

**Return flow:** Water that is returned to surface or ground water after use or wastewater treatment, and becomes available for reuse. Return flow can go directly to surface water, directly to ground water through an injection well or infiltration bed, or indirectly to ground water through a septic system.

**Self-disposed water:** Water returned to the ground (septic systems) by a user or group of users that are not on a wastewater-collection system.

**Self-supplied water:** Water withdrawn from a ground- or surface-water source by a user and not obtained from a public or private water-supply system.

**Standard Industrial Classification (SIC) code:** Four-digit codes established by the U.S. Office of Management and Budget and used in the classification of establishments by type of activity in which they are engaged. The IWR-MAIN coefficients for industrial and commercial water use are based on the first two digits.

**Surface-water return flow:** Effluent from a discharge pipe to a river or lake.

**Wastewater:** Water that carries wastes from domestic, industrial, and commercial consumers; a mixture of water and dissolved or suspended solids.

**Wastewater treatment:** The processing of wastewater for the removal or reduction of contained solids or other undesirable constituents.

**Wastewater-treatment return flow:** Water returned to the hydrologic system by wastewater-treatment facilities. Also referred to as effluent water.

**Water purification:** The processes that withdrawn water may undergo prior to use, including chlorination, fluoridation, and filtration.

**Water supply:** All of the processes that are involved in obtaining water for the user before use. Includes withdrawal, water treatment, and other distribution.

**Water use:** (1) In a restrictive sense, the term refers to water that is actually used for a specific purpose, such as for domestic use, irrigation, or industrial processing. (2) More broadly, water use pertains to human interaction with and impact on the hydrologic cycle, and includes elements such as water withdrawal, distribution, consumptive use, wastewater collection, and return flow.

**Withdrawal:** The removal of surface water or ground water from the hydrologic system for use, including public-water supply, industry, commercial, domestic, irrigation, livestock, and thermoelectric power generation water uses.