ESTIMATION OF WATER WITHDRAWAL AND DISTRIBUTION, WATER USE, AND WASTEWATER COLLECTION AND RETURN FLOW IN CUMBERLAND, RHODE ISLAND, 1988

By M. A. Horn, P. A. Craft, *and* Lisa Bratton

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CONVERSION FACTORS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.59	square kilometer
gallon per day (gal/d)	0.003785	cubic meter per day
million gallons per day (Mgal/d)	3,785	cubic meter per day
inch per year (in/yr)	0.0476	million gallons per day

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ABSTRACT

Water-use data collected in Rhode Island by different State agencies or maintained by different public water suppliers and wastewater-treatment facilities need to be integrated if these data are to be used in making water-resource management decisions. Water-use data for the town of Cumberland, a small area in northeastern Rhode Island, were compiled and integrated to provide an example of how the procedure could be applied. Integration and reliability assessment of water-use data could be facilitated if public suppliers, wastewater-treatment facilities, and State agencies used a number of standardized procedures for data collection and computer storage.

The total surface water and ground water withdrawn in Cumberland during 1988 is estimated to be 15.39 million gallons per day (Mgal/d) of which 11.20 Mgal/d was exported to other towns. Water use in Cumberland included 2.51 Mgal/d for domestic use, 0.68 Mgal/d for industrial use, 0.27 Mgal/d for commercial use, and 0.73 Mgal/d for other uses, most of which were unmetered use. Disposal of wastewater in Cumberland included 2.03 Mgal/d returned to the hydrologic system and 1.73 Mgal/d exported from Cumberland for wastewater treatment. Consumptive use during 1988 is estimated to be 0.43 Mgal/d.

INTRODUCTION

In Rhode Island, water withdrawal is approaching the operational capacities of developed water supplies (Rhode Island Division of Planning, 1988). This situation could be alleviated through development of new sources of water supply, more efficient use of existing supplies, or both. Evaluation of these alternatives requires access to accurate, comprehensive, and comparable water-use data. Collection, analysis, computer storage, and dissemination of water-use data is costly and time consuming, especially if undertaken at a time of crisis. By implementing a well-planned and continuous water-use data program, collection of data not only would be more efficient and less costly than at present but would also generate data of known reliability. The data can be used to understand current supply and demand relations, facilitate prediction of future demands, develop plans to ensure sufficient supplies for future use, and monitor the effectiveness of conservation measures.

The U.S. Geological Survey (USGS), in cooperation with the Rhode Island Department of Environmental Management and the Rhode Island Governor's Office of Housing, Energy, and Intergovernmental Relations (GOHEIR), has been working toward the development of a comprehensive, up-to-date, and reliable water-use data base. The first phase in developing the data base was to prepare a report (Horn and Craft, 1991) that describes six processes incorporating all aspects of water use, defines data requirements, and discusses the major issues involved in developing a water-use data program. The second phase was to apply the guidelines provided in that report to a limited area to demonstrate how data compilation, analysis, and computer storage and retrieval would result in the water-use data needed by Rhode Island water-resource managers and planners. The town of Cumberland, R.I., was chosen for the demonstration phase of the study because its public supply includes not only water from ground-water and surface-water sources within the town but also water purchased from another public supplier. GOHEIR supported this program, assuming that the program would result in reduced energy and water consumption in Rhode Island.

A complete water-use data program examines all six water-use processes: (1) **withdrawal**[1], (2) **water use**, (3) **return flow**, (4) **consumptive use**, (5) **treatment**, and (6) **conveyance** (Horn and Craft, 1991), which are described briefly in the glossary. The interrelations of the water-use processes are illustrated in figure 1. The six processes are discussed in three sections in this report: withdrawal and **distribution**, which combines the three supply processes--withdrawal, **water treatment**, and distribution conveyance; water use, including consumptive use; and **wastewater collection** and return flow, which combines the three **disposal** processes--wastewater-collection conveyance, **wastewater treatment**, and return flow. This organization parallels the three main institutional water-resource management programs: allocation, conservation and demand management, and discharge.

Purpose and Scope

The purpose of this report is to demonstrate integration of water-use data collected by different State agencies or maintained by different public suppliers and wastewater-treatment facilities. The methods used for this case study of Cumberland, R.I., can be applied to a water-use data program for the rest of the State. The report presents a brief discussion of data compilation, organization and computer storage, and analysis. A detailed description of the methods used and the resulting water-use data are presented on withdrawal, distribution, use, wastewater collection, return flow, and import of water into and export of water out of Cumberland. At the end of each section, an overview provides a discussion of how water that is withdrawn, distributed, used, collected, and returned in the study area affects the availability and distribution of water resources.

[1] Terms in bold print are defined in the glossary in the back of this report.

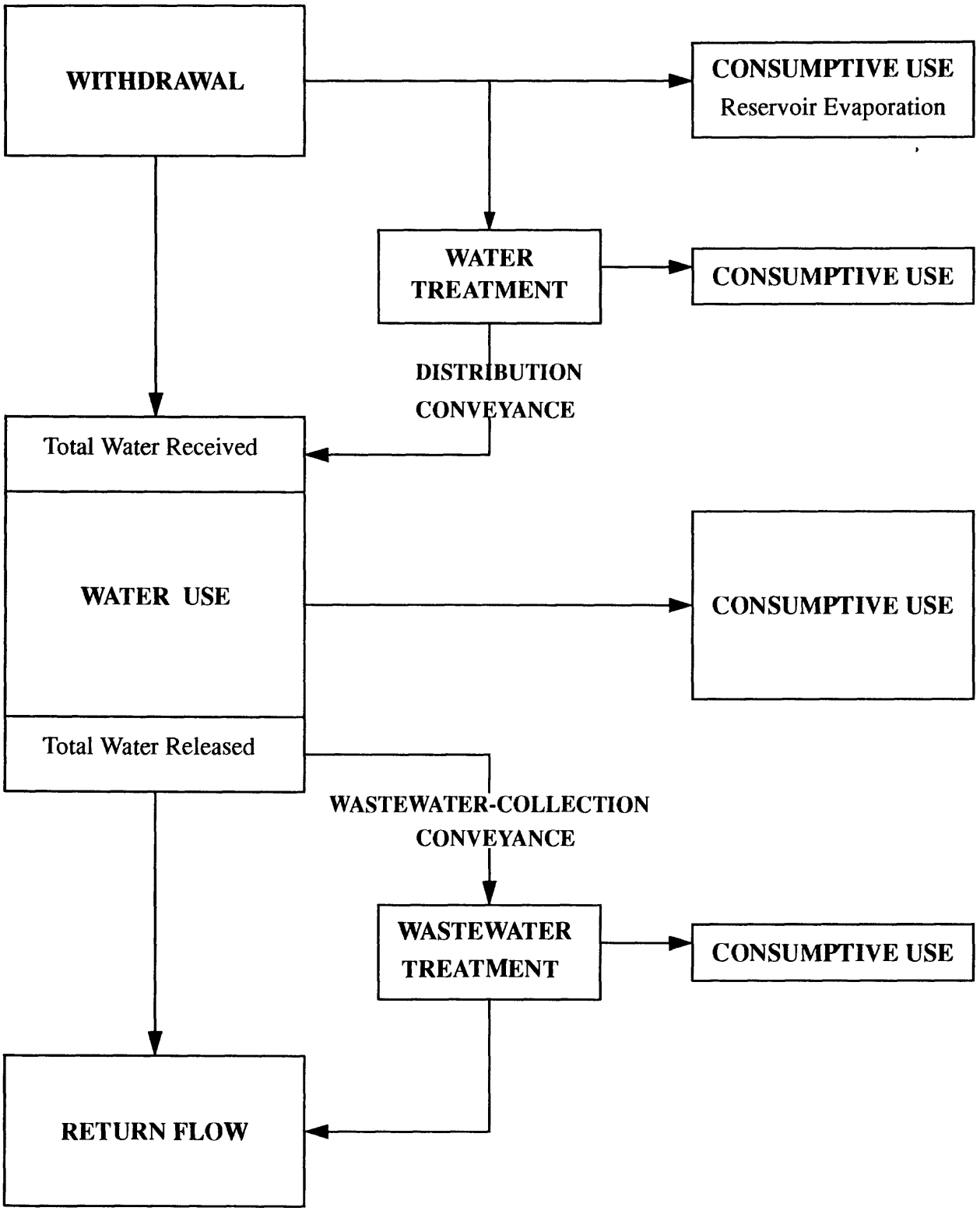


Figure 1.--General water-use flow diagram. (Modified from Horn and Craft, 1991, fig. 3.)

Description of Study Area

The town of Cumberland covers 28.64 mi^2 of Providence County, which is in the northeastern corner of Rhode Island, approximately 10 mi north of Providence and 50 mi southwest of Boston. Cumberland is roughly wedge-shaped, with the apex to the south (fig. 2). The town is bounded on the north and east by the State of Massachusetts; on the northwest by the town of Woonsocket, R.I.; and on the west and south by the Blackstone River, which separates Cumberland from the towns of Lincoln, to the west, Central Falls, to the south, and Pawtucket to the southeast.

The 1988 estimated population of Cumberland was 28,350 (Rhode Island Division of Planning, Department of Administration, 1990), an increase of 5 percent from the population of 27,069 in 1980. The population density is relatively high, at 990 people per square mile overall, and is highest in three areas: (1) in the southern tip; (2) in the west along Highway 122, which roughly borders the Blackstone River; and (3) in the east along Highway 114, near the Massachusetts border.

The sources of water in Cumberland include precipitation and surface-water and ground-water storage. The average precipitation for Rhode Island is 45.4 in/yr (Johnston and Baer, 1990), which, when applied over the area of Cumberland (28.64 mi^2), is roughly equivalent to 61.9 Mgal/d. The average value for evapotranspiration in Rhode Island is 21 in/yr (Johnston and Baer, 1990), which is roughly equivalent to 28.7 Mgal/d in Cumberland. Thus, the precipitation available for surface-water runoff and ground-water recharge in Cumberland is approximately 33.3 Mgal/d, or 53.8 percent.

Cumberland is entirely within the Blackstone River drainage basin. However, Abbott Run, a major tributary to the Blackstone River along Cumberland's eastern edge, is considered a distinct subbasin in this report because separate public-supply and wastewater-collection pipes have been placed in both valleys. The Abbott Run subbasin is 16.90 mi^2 (59 percent of Cumberland), and the Diamond Hill and Arnold Mills Reservoirs are the major standing water bodies. The Blackstone River subbasin in Cumberland is 11.74 mi^2 (41 percent of Cumberland), and Sneech Pond is the only major standing water body

Each river basin in Cumberland is underlain by crystalline rock (bedrock) which is covered by till. Stratified drift deposits lie in the center of each valley and form major sand-and-gravel aquifers (referred to as "ground-water reservoirs" in Rhode Island): the Blackstone ground-water reservoir and the Abbott Run ground-water reservoir. Small quantities of water that are generally sufficient for domestic supply are available from the bedrock and from till that covers the bedrock.

Acknowledgments

Most of the data used in preparing the report were obtained from the Cumberland Water Department, the Pawtucket Water Supply Board, and the Blackstone Valley District Commission (which became part of the Narragansett Bay Commission, January 1992). The cooperation of the personnel from the three utilities is gratefully acknowledged.

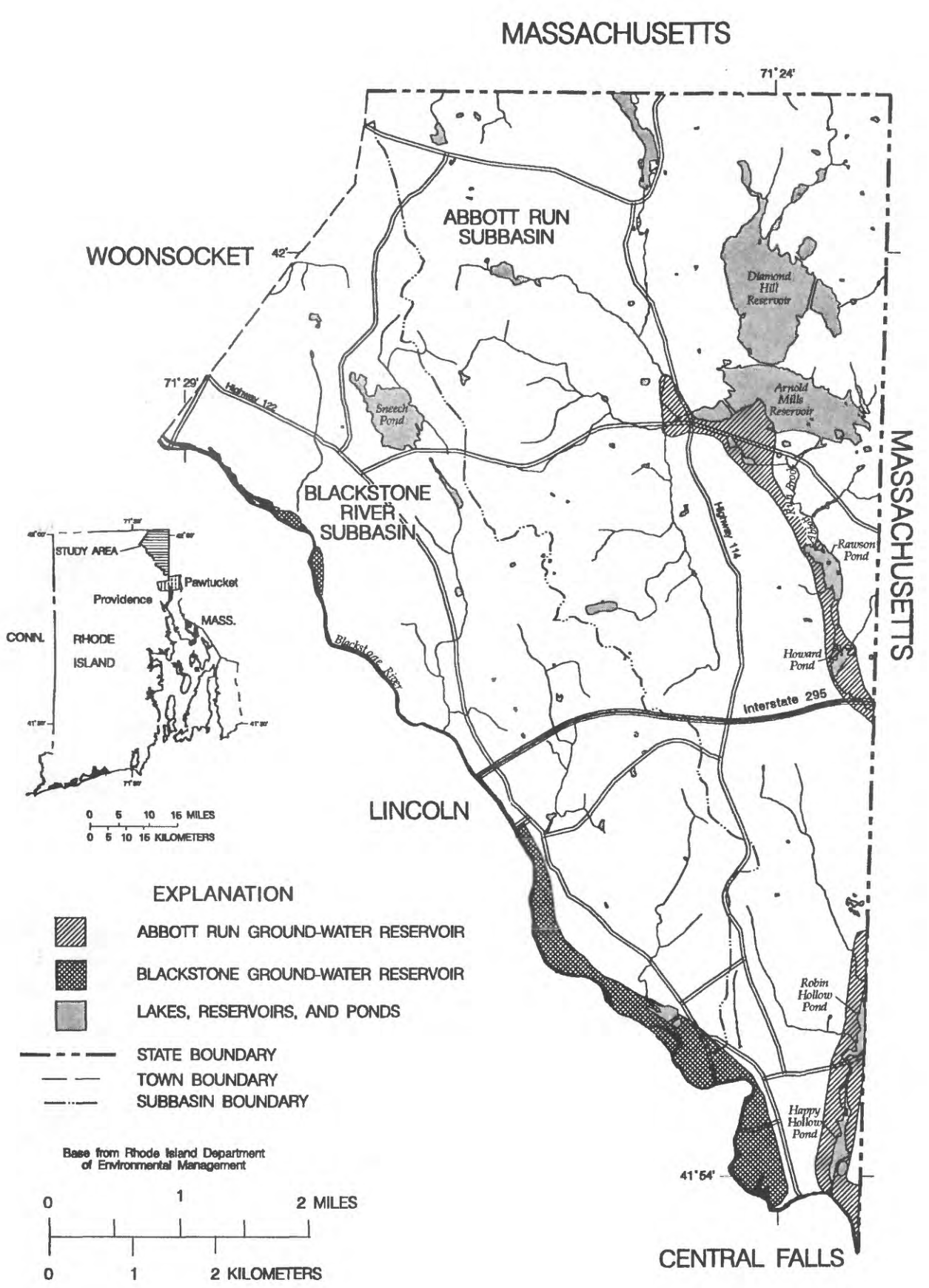


Figure 2.--Hydrologic features in Cumberland, Rhode Island. (Data from University of Rhode Island Geographic Information System.)

DATA MANAGEMENT

The sources of statewide and local data were identified, and data were compiled. The data were then organized and analyzed for accuracy and reliability, particularly with regard to the volumes of water used. The data were entered into the USGS site-specific water-use data base (SSWUDS). Finally, the data were retrieved and analyzed to evaluate water-use patterns. The method and results obtained in the final step are described in the water withdrawal and distribution, water use, and wastewater-collection and return-flow sections.

Most of the data used in this report were collected and maintained by the two public suppliers, Cumberland Water Department (Cumberland WD) and Pawtucket Water Supply Board (Pawtucket WSB), and the wastewater-treatment facility, Blackstone Valley District Commission (Blackstone VDC), because they supply or dispose most of the water used in Cumberland. In this respect, Cumberland is typical of highly urbanized areas in the northeastern United States because most of the water used is supplied and disposed of by public facilities.

Data Compilation

Compilation of water-use data for Cumberland began with an inventory of data sources available throughout the State and the requisition of data from these sources (table 1). Water-use data were acquired to describe each water-use activity. Minimum data required to meet this objective are described in Horn and Craft (1991). USGS staff worked closely with staff from Cumberland WD, Pawtucket WSB, and Blackstone VDC to collect and review data. Contact was also made with some of the industries in the area for information on water supply.

Data Organization and Computer Storage

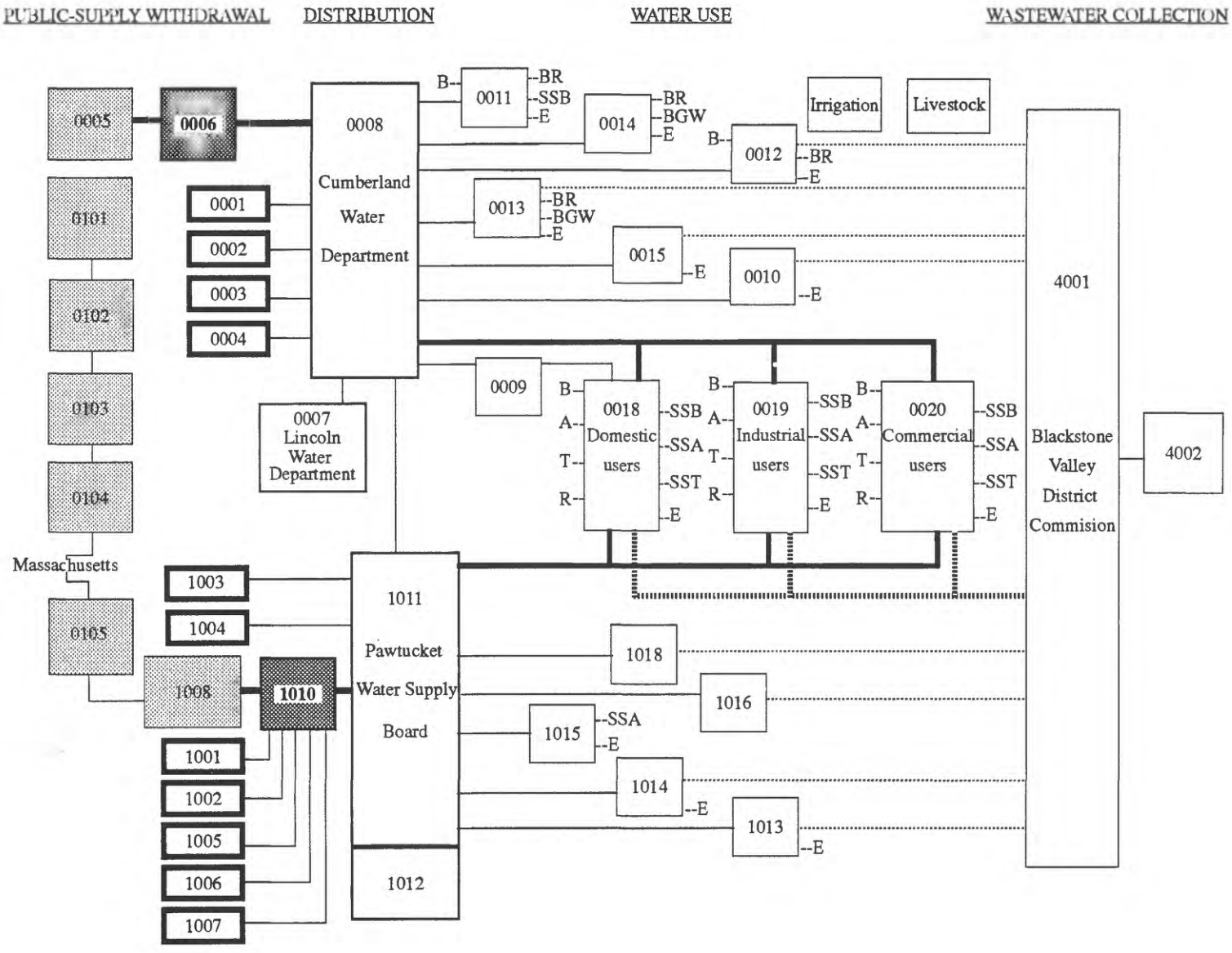
A schematic diagram (fig. 3) was developed to clarify how water is moved throughout Cumberland from individual and aggregate withdrawal points to users and, ultimately, to individual and aggregate return-flow points in the hydrologic environment. The diagram establishes the relation between public suppliers, users, and the wastewater-collection facility, and it illustrates the interrelation between the water-use activities in Cumberland.

The water-use data were organized by whether they documented (1) supply, which includes withdrawal, water treatment, and distribution conveyance; (2) use, which includes water received by users, consumptive use, and water released by users; or (3) disposal, which includes wastewater-collection conveyance, wastewater treatment, and return flow. The data were also organized by the major use categories: public supply, industrial, commercial, domestic, irrigation, and livestock. Although consumptive use occurs primarily during use, some consumptive use occurs during supply and disposal.

Table 1.--Sources of water-use data

[Dept, Department; RI, Rhode Island; RIPDES, Rhode Island Pollutant Discharge Elimination System; WD, Water Department; WSB, Water Supply Board]

Type of data	Source of data
SUPPLY	
Withdrawal:	
Public supply	RI Water Resources Board; RI Dept. of Health--community suppliers
Domestic	RI Dept of Health--noncommunity suppliers; U.S. Bureau of Census; Cumberland WD; Pawtucket WSB
Industrial	RI Dept of Environmental Management-RIPDES; RI Dept. of Commerce--Directory of manufacturers data base; Blackstone Valley District Commission; Cumberland WD; Pawtucket WSB
Commercial	RI Dept of Health--noncommunity suppliers
Livestock, irrigation	RI Dept of Environmental Management Division of Agriculture--1990 RI farm survey
Treatment (water)	Cumberland WD, Pawtucket WSB
Distribution	RI Water Resources Board; Cumberland WD; Pawtucket WSB
WATER USE	
Domestic	Same as withdrawals
Industrial	Same as withdrawals
Commercial	RI Dept of Health--noncommunity suppliers; Cumberland WD; Pawtucket WSB
Livestock, irrigation	Same as withdrawals
DISPOSAL	
Wastewater collection	Blackstone Valley District Commission
Treatment (wastewater)	Blackstone Valley District Commission
Return flow:	
Domestic	Blackstone Valley District Commission, Cumberland WD; Pawtucket WSB; U.S. Bureau of Census
Industrial	Same as withdrawals
Commercial	Blackstone Valley District Commission; Cumberland WD; Pawtucket WSB
Livestock, irrigation	Same as withdrawals


PUBLIC-SUPPLY WITHDRAWAL
DISTRIBUTION
WATER USE
WASTEWATER COLLECTION
0005
0006
0101
0102
0103
0104
Massachusetts
0105
0001
0002
0003
0004
0008
Cumberland Water Department
0007 Lincoln Water Department
0011
0014
0012
0013
0015
0010
0009
0018 Domestic users
0019 Industrial users
0020 Commercial users
Irrigation
Livestock
4001
Blackstone Valley District Commision
4002
1003
1004
1008
1010
1001
1002
1005
1006
1007
1011 Pawtucket Water Supply Board
1012
1018
1016
1015
1014
1013
B
A
T
R
BR
BGW
SSB
SSA
SST
E

EXPLANATION

0001 Water-user identification number (see list to right)

1003 Public supply wells

1008 Public supply reservoirs

1010 Water treatment

1011 Users

PUBLIC PATHS

Supply paths

Major supply paths

Disposal paths

Major disposal paths

ABBREVIATIONS

B - Blackstone ground-water reservoir
A - Abbott Run ground-water reservoir
T - Till
R - Bedrock
E - Evaporation
BR - Discharge to Blackstone River
BGW - Discharge to Blackstone ground-water reservoir
SSB - Septic system in the Blackstone ground-water reservoir
SSA - Septic system in the Abbott Run ground-water reservoir
SST - Septic system in till area

Water-user identification number — Description

0001 - Abbott Run Well 2 and treatment
0002 - Abbott Run Well 3 and treatment
0003 - Manville Well 1 and treatment
0004 - Manville Well 2 and treatment
0005 - Sneech Pond
0006 - Sneech Pond treatment facility
0007 - Lincoln Water Department
0008 - Cumberland Water Department distribution system
0009 - Lippitt Estates Community Association
0010 - Unmetered and unaccounted water
0011 - Electroformax Laboratories, Inc.
0012 - Peterson Puritan, Inc.
0013 - Pacific Anchor Chemical Corp.
0014 - The Okonite Company
0015 - Maplewood Condominiums
0018 - Domestic aggregate
0019 - Industrial aggregate
0020 - Commercial aggregate
0101 - Diamond Hill Reservoir
0102 - Arnold Mills Reservoir
0103 - Rawson Pond
0104 - Howard Pond
0105 - Robin Hollow Pond
1001 - Pawtucket Water Supply Board Well 2
1002 - Pawtucket Water Supply Board Well 3
1003 - Pawtucket Water Supply Board Well 4
1004 - Pawtucket Water Supply Board Well 5
1005 - Pawtucket Water Supply Board Well 6
1006 - Pawtucket Water Supply Board Well 7
1007 - Pawtucket Water Supply Board Well 8
1008 - Happy Hollow Pond
1010 - Pawtucket Water Supply Board treatment facility
1011 - Pawtucket Water Supply Board distribution system in Cumberland
1012 - Pawtucket Water Supply Board distribution system outside Cumberland
1013 - Pontiac Weaving Corp.
1014 - Standard Nut and Bolt Company
1015 - Ann and Hope Factory Outlet
1016 - Mackland Realty, Inc.
1018 - Unmetered and unaccounted water
4001 - Blackstone Valley District Commission wastewater collection system
4002 - Blackstone Valley District Commission wastewater treatment facility

Figure 3.--Movement of water before, during, and after use in Cumberland, Rhode Island. (Sources of data are listed in table 1.)

Data on the owner or user were reviewed for completeness and accuracy. In this report, the entity that withdraws, treats, distributes, or uses freshwater or collects and treats wastewater is called the user. All users were assigned unique water-user identification numbers (WUID) (fig. 3) that were stored in SSWUDS with their use category and location data. Detailed or site-specific data for **major users** (those who withdraw, distribute, or use water, or collect or return wastewater an average of more than 10,000 gal/d (0.01 Mgal/d)) were compiled, analyzed, and entered into the computer data base. **Minor users** (those who withdraw, distribute, or use water, or collect or return wastewater an average of less than 10,000 gal/d) were aggregated by use category. For example, WUID 0018 in figure 3 is an aggregate of all domestic users in Cumberland.

Data describing where specific water-use activities occur, called measurement points, were reviewed. Measurement points provide two important functions: (1) location in terms of latitude and longitude of the water-use activity (withdrawal, treatment, distribution, use, wastewater collection, wastewater treatment or return flow), and (2) linkage between where the water was before it arrived at the point of activity and where the water was sent after it departed the point of activity. These data allow water to be tracked as it moves from withdrawal through return flow. Four action codes were used to define movement: withdrawal (from ground water or surface water), deliveries (to measurement points), releases (from measurement points), and returns (to ground water, surface water, or to the atmosphere as evaporation). Aggregates were given separate measuring points to denote each supply source (public supplier, aquifer, or surface-water body) and form of disposal (wastewater-collection system or aquifer receiving water from septic system).

Data were entered into SSWUDS. Figure 3, which was used to depict the relation between public suppliers, users, and the wastewater-collection facility, was also used to determine how the user, measurement points, and annual volumes were to be stored in SSWUDS. Each user is linked by the WUID to at least one measurement point. The measurement points are stored in SSWUDS with unique measurement point identification numbers (MPID), action codes to describe the water movement, and location data. Each measurement point is linked by the WUID and MPID to annual or monthly volumes. The annual or monthly volumes are designated as either metered (M) or estimated (E); and the reliability of the data is rated as excellent (E), good (G), fair (F), or poor (P).

Data Analysis

Data on the volume of water moving through each measurement point were analyzed. Metered data were available on the volume of water used by virtually all customers of the Cumberland WD, Pawtucket WSB, and Blackstone VDC. The meter readings were used to determine major users, identify self-supplied and self-disposed users, and determine the volume of water delivered for domestic, industrial, and commercial uses. Careful analysis of metered water-use data is critical; the data may be unreliable because of inconsistent record-keeping or because there is no meter-replacement or meter-calibration program to ensure meter reliability. Estimates for unmetered water use can be made by use of a variety of methods, including coefficients, which need to be evaluated for applicability and accuracy.

Cumberland WD, Pawtucket WSB, and Blackstone VDC divide their customers into large and small users, frequently on the basis of criteria that are specific to the utility and that may reflect past, current, or anticipated volumes delivered to or released by the user. The distinction between **large** and **small users** is made by the utility and is not the same as major and minor users. Meters of large users are read monthly or quarterly. The volume of water delivered to small users can be (1) calculated from annual meter readings, (2) calculated from meter readings sent in by users, or (3) estimated on the basis of the number of household units per meter. Although large users are commonly classified by the utility as "industrial" because of the meter size, the actual use of the water may be for industrial, commercial, or domestic purposes. Volumes delivered or released, based on meter readings, for the large users (as defined by each utility) are listed in appendixes 1-6.

Data for all metered customers for each of the three utilities were examined to determine which users included more than a single household. This examination assisted in (1) the identification of users that were self-supplied (appearing on Blackstone VDC lists but not on either Cumberland WD or Pawtucket WSB lists) or self-disposed (appearing on either Cumberland WD or Pawtucket WSB lists but not on Blackstone VDC lists), and (2) the determination of accurate domestic, commercial, and industrial deliveries and releases. This task was difficult because each utility had different record-keeping procedures.

Problems in analyzing and matching utilities' customer lists arose when the data were used for purposes other than those for which the data were originally collected; however, minor changes in how the data are collected could eliminate many of these problems. For example, comparison of customer lists between the public suppliers and Blackstone VDC would be facilitated if the complete address or the lot-block number for the site of use was available, not just the street name or the address for an off-site concern (such as a landlord) who pays the bill. Development of a method to simultaneously update metering and billing account names at the public-supply and wastewater-treatment facilities also would help. Identification of self-supplied or self-disposed users would be simplified by flagging the users on wastewater-collection systems in the Cumberland WD and Pawtucket WSB data files and the users on public supply in the Blackstone VDC data files. Determination of whether the water was used for domestic, commercial, or industrial purposes would be easier if the name or Standard Industrial Classification (SIC) code for commercial or industrial users was provided.

Readings from the utilities' master or main meters were considered reliable for determination of the volume of water withdrawn and treated because these meters are monitored regularly and recalibrated as necessary. Household meters are not as well maintained, however, and they can lose accuracy. Other problems with meter readings concern reader error, particularly when the meter reaches it highest number and starts again at zero. Errors occur more frequently when users send in their own meter readings than when the meters are read by utility meter readers. These errors may not be caught if the readings are not analyzed before entry into the billing system. When an incorrect meter reading results in an abnormally high water bill, the customer may complain and get the bill adjusted, but the original recorded meter reading may not be updated. This problem seemed to occur several times in one of the sets of meter readings, which resulted in high residential volumes.

Frequently, meter readings were not available. When the volume was assumed not to change, such as between a withdrawal from a well and receipt by a treatment facility, the same volume was recorded at both measurement points. The volume released from a treatment facility

was calculated by subtracting an estimate for the volume of water lost during treatment from the metered volume received at the treatment facility or the volume of water received at a treatment facility was estimated by adding an estimate for the volume of water lost to the metered volume released from a treatment facility. In other cases, water-use estimates were made on the basis of number of employees, acres irrigated, number of livestock, or other variables related to the volume of water used. Documentation of how the volume was determined is important because some estimates were based on very limited information. Estimates were adjusted as new information became available.

The ease with which data analysis can be done depends on the accuracy, reliability, and standardization of data collected and maintained by State agencies or by individual public suppliers and wastewater-treatment facilities. Accuracy of data on deliveries to customers could be improved if reported meter readings were run through a verification program to detect anomalies. Reliability of data could be improved by documentation of the type and method of measurement and the accuracy of the reported volume of water use. Data standardization may be facilitated by adopting consistent definitions of user categories that are based on the SIC Codes, using the complete address for users, noting whether supply or disposal is public or private, and recording the volume of water at critical points during use. Critical use points include withdrawal, after water treatment, at the point of delivery for use, after use by high-volume users, at major wastewater-collection points, at the point of entry into a wastewater-treatment facility, and at return to the resource. Currently (1991), Rhode Island has not recommended any specific standards to be followed. Although lack of standardization made data compilation and analysis difficult, it was possible to complete the water-use data review for Cumberland. Discussions on the estimation of unmetered use by use of coefficients are presented in the subsequent sections of this report.

ESTIMATION OF WATER WITHDRAWAL AND DISTRIBUTION

Three of the six water-use processes are involved in supplying the user with water: withdrawal, water treatment, and distribution conveyance. Withdrawal and distribution are the critical supply processes. Water treatment is included as a supply process because it provides the link between withdrawal and distribution and includes water used in filter backwashing. Public supply is water that is withdrawn and subsequently sold, or **delivered**, to users. Self supply, water withdrawn directly by users, is discussed last in this section because some estimates for self supply depend on trends observed in public-supply distribution.

Supply in Cumberland (fig. 4) includes all the major withdrawal points, including public-supply wells and reservoirs, self-supply wells, surface-water intakes and treatment facilities, distribution points (which include storage tanks), interconnections (the point where two public-supply systems can sell or purchase water from each other), and the areal extent of the Cumberland WD, Pawtucket WSB, and Lippitt Estates Community Association (Lippitt ECA) distribution systems.

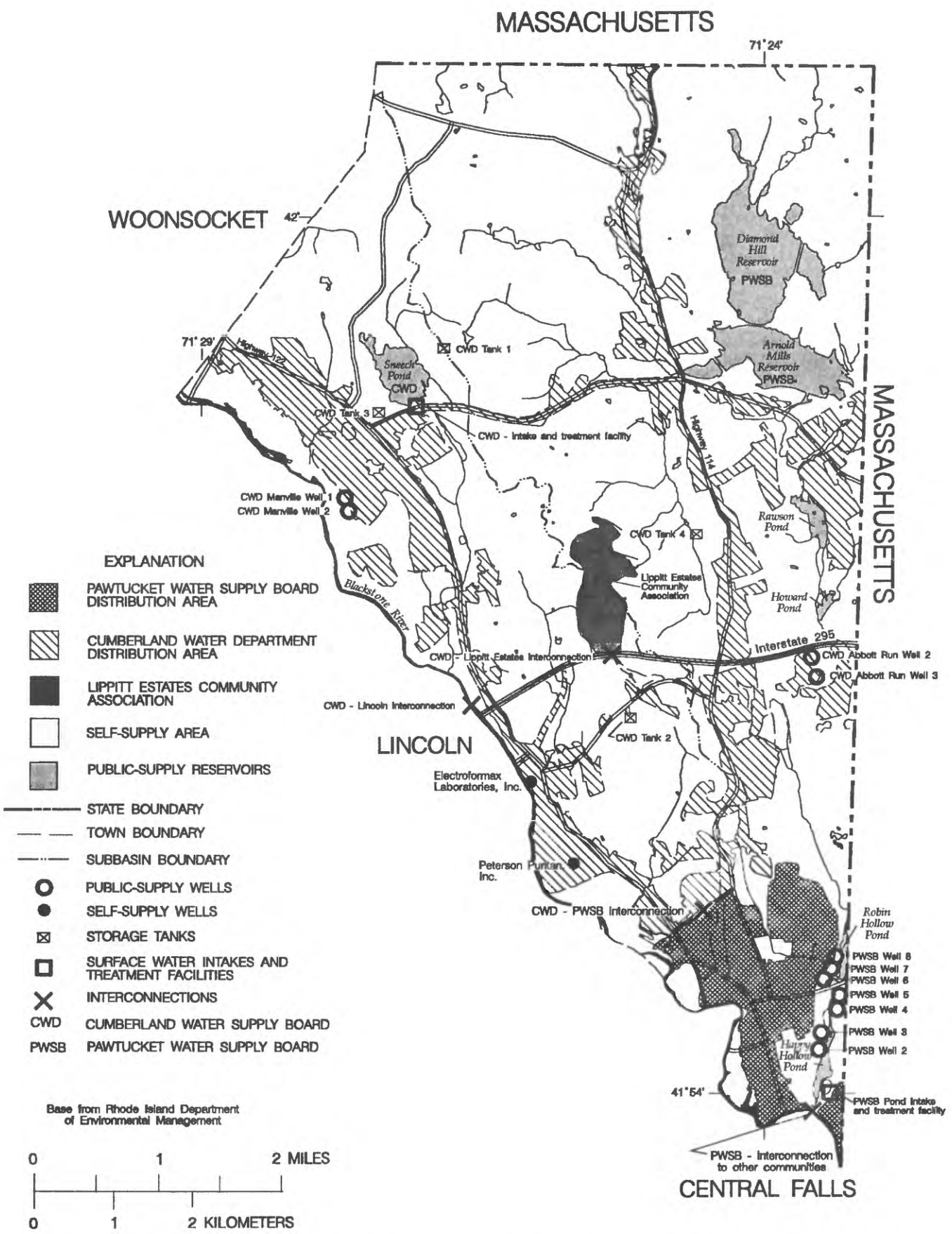


Figure 4.--Ground-water and surface-water withdrawal points, treatment facilities, and distribution areas in Cumberland, Rhode Island. (Sources of data are listed in table 1.)

Public Supply

The U.S. Environmental Protection Agency (USEPA) defines a community public-water-supply system as one that contains more than 15 service connections or serves more than 25 individuals. The term "public supply" is used because the public is being supplied by the water, not because the entity withdrawing the water is publicly owned.

Withdrawal

Withdrawal, the removal of surface water or ground water for use, is the first of the three processes included in public supply. Withdrawal measurement points can be wells or intake pipes on streams, lakes, or reservoirs. The Rhode Island Department of Health (RIDOH) has records on three community public-supply systems that serve Cumberland. Two public suppliers withdrew water during 1988: Cumberland WD, which withdrew 1.84 Mgal/d, and Pawtucket WSB, which withdrew 13.27 Mgal/d. The rate of withdrawal for public supply from individual sources and the rate for water that is returned during water treatment are presented in table 2. A third public supplier, Lippitt ECA, purchased all of its water from Cumberland WD in 1988.

During 1988, the Cumberland WD withdrew water from three primary sources: one surface-water body and two aquifers. The surface-water source, Sneech Pond (0005 on fig. 3), is in the west-central part of Cumberland in the Blackstone River subbasin (fig. 2). The Cumberland WD estimated the safe yield of this pond at 0.7 Mgal/d. Water is withdrawn through a pumping station on the southern shore of Sneech Pond. The rate of water withdrawal from Sneech Pond is not measured at the pumping station. Withdrawal during 1988 from Sneech Pond was estimated at 0.70 Mgal/d on the basis of a metered value of 0.70 Mgal/d as outflow from the treatment facility plus an estimate of less than 0.01 Mgal/d (4,500 gal/d) return flow of filter backwash water.

Two sand and gravel aquifers are used by the Cumberland WD: the Blackstone and Abbott Run ground-water reservoirs (fig. 2). Cumberland WD has two public water-supply wells in each aquifer. During 1988, withdrawal from Manville wells 1 (0003) and 2 (0004), which tap the Blackstone ground-water reservoir along the western border of the town (fig. 4), was measured as 0.41 and 0.45 Mgal/d, respectively. Withdrawal from Abbott Run wells 2 (0001) and 3 (0002), which tap the Abbott Run ground-water reservoir on the eastern boundary of the town, was measured as 0.09 and 0.19 Mgal/d, respectively. Water withdrawn from each of the four wells is treated at its **wellhead** before entering the distribution system (0008).

The Pawtucket WSB withdrew water from the 28 mi^2 Abbott Run subbasin (fig. 3), which includes water contributed from the Massachusetts part of the basin. Water is withdrawn from the downstream end of a chain of five reservoirs and from seven wells. As shown on the map in figure 4 and diagramed in figure 3, the reservoir system is headed by Diamond Hill Reservoir, from which water is transported by way of Abbott Run through Arnold Mills Reservoir, Rawson Pond, into Massachusetts, back into Rhode Island, through Robin Hollow Pond, and finally into Happy Hollow Pond in the southeastern corner of Cumberland. The relative volume contributed by each reservoir is not currently collected by Pawtucket WSB.

Pawtucket WSB has estimated the safe yield of the reservoir system at 21.0 Mgal/d. Water is withdrawn from Happy Hollow Pond (1008) and delivered to the Mill Street treatment facility (1010) in Cumberland. The volume of water is metered before and after the water enters the treatment facility. During 1988, 12.72 Mgal/d was withdrawn from Happy Hollow Pond.

Table 2.--Withdrawal and filter-backwash return flow for public supply in Cumberland, 1988

[Data from Cumberland Water Department and Pawtucket Water Supply Board. Name of aquifer: ARGWR, Abbott Run ground-water reservoir; BGWR, Blackstone ground-water reservoir. Public supply processes: E, estimated; M, metered; <, actual value is less than value shown. --, no data or not applicable]

Public supplier	Name of measurement point	Name of aquifer	Public supply processes, in millions of gallons per day: Water withdrawn	Water treated	Water returned
Cumberland Water Department	Sneech Pond	--	[1]0.70 E	0.70 M	<0.01 E
	Manville well 1	BGWR	.41 M	.41 M	--
	Manville well 2	BGWR	.45 M	.45 M	--
	Abbott Run 2	ARGWR	.09 M	.09 M	--
	Abbott Run 3	ARGWR	.19 M	.19 M	--
Total for Cumberland			1.84	1.84	<.01
Pawtucket Water Supply Board	Happy Hollow Pond	--	12.72 M		
	Well 2	ARGWR	[2].10 E	[3]12.99 E	[3].19 E
	Well 3	ARGWR	[2].09 E		
	Well 6	ARGWR	[2].09 E		
	Well 7	ARGWR	[2].09 E		
	Well 8	ARGWR	[2].09 E		
	Well 4	ARGWR	.05 M	.05 M	--
	Well 5	ARGWR	.04 M	.04 M	--
Total for Pawtucket			13.27	13.08	.19
Total for all water departments			15.11	14.92	.19

[1]The withdrawal from Sneech Pond was measured as it was released from the treatment facility and did not include the volume of water used to backwash the filters. The value shown includes backwash water of less than 0.01 Mgal/d based on the facility manager's estimate that the water was pumped through the filters for 3 hours a day at a rate of 25 gallons per minute.

[2]The volumes of water withdrawn from PWSB wells 2, 3, 6, 7, and 8 were not metered; the monthly volumes were estimated from records for Happy Hollow Pond, which indicated that withdrawal from the Pond constituted 96.5 percent of the intake at the treatment facility and that the unmetered wells constituted the remaining 3.5 percent. Withdrawals from individual unmetered wells were estimated by dividing the total by 5.

[3]Value is total for wells 2, 3, 6, 7, and 8.

Ground water was withdrawn from seven wells that tap the Abbott Run ground-water reservoir. Five wells, (2 (1001), 3 (1002), 6 (1005), 7 (1006), and 8 (1007)) are situated around Happy Hollow Pond and supplement withdrawal from the pond. The wells are unmetered, and the water is pumped and stored in the **clearwell** at the treatment facility. The wells are used mostly in February and March, when the salt concentration in the surface water increases because of runoff from roads, and in the summer, when water demand is high. The monthly volumes for the five wells were estimated on the basis of records for Happy Hollow Pond, which indicated that withdrawal from the Pond constituted 96.5 percent of the intake at the treatment facility and that the unmetered wells constituted the remaining 3.5 percent. Withdrawal from individual unmetered wells were estimated by dividing the total by 5. During 1988, total withdrawal from these wells was estimated at 0.46 Mgal/d. Pawtucket wells 4 (1003) and 5 (1004), located south of Robin Hollow Pond near the Massachusetts border, pump directly into the distribution system. These wells are metered and treated at the wellheads. During 1988, water was withdrawn from these two wells only during July and August for a combined total 0.09 Mgal/d.

Water Treatment

Water treatment, the second process in public supply, consists of the processes that withdrawn water may undergo before use. Water treatment is intended to ensure compliance with appropriate State or Federal standards for drinking water or otherwise to improve water quality. Data on the rate of water treatment in Cumberland are presented in table 2.

The Cumberland WD operates two types of treatment systems: the main system at Sneech Pond and smaller systems at each wellhead. The facility at Sneech Pond treats an average of 0.70 Mgal/d and can treat as much as 1.45 Mgal/d. The treatment consists of flocculation, pH buffering, settling, rapid sand filtration, chlorination, and fluoridation. After treatment, the water flows into a clearwell for additional clarity by means of settling. Water from each of the four wells is treated at the wellhead. Treatment consists of pH buffering, fluoridation, and, on occasion during the summer, chlorination. Although no measurements are made at the wellhead after treatment, the volume of water treated and released is assumed to be equal to the volume withdrawn (1.14 Mgal/d).

The Pawtucket WSB also operates two types of treatment systems. Water withdrawn from Happy Hollow Pond (12.72 Mgal/d) and the nearby five wells (2, 3, 6, 7, and 8) (0.46 Mgal/d) is treated at the facility on Mill Street in Cumberland. The water treatment consists of aeration, flocculation, pH buffering, settling, filtration, chlorination, and fluoridation. After treatment, the water flows into a 1.5-Mgal clearwell for settling and storage. Pawtucket wells 4 and 5 are each treated at the wellhead. Although no measurements are made at the wellhead after treatment, the volume of water treated and released is assumed to be equal to the volume withdrawn (0.09 Mgal/d).

Distribution Conveyance

Distribution conveyance, the third process in public supply, is the process of conveying water from a public supplier's points of withdrawal or treatment through the distribution system and delivering it to the user. Distribution includes sale or purchase of water through interconnections to other public-supply systems and delivery of water directly to customers within the public supplier's service area.

Conveyance Between Public Suppliers

In the Cumberland WD system, water treated in the Sneech Pond Treatment Facility (0006) enters the distribution system (0008) at the facility, and the treated ground water enters the distribution system at each of the four wellheads (fig. 3). The Cumberland WD maintains interconnections with three other public suppliers: Pawtucket WSB (1011), Lincoln Water Department (0007), and Lippitt ECA (0009). The largest interconnection is with Pawtucket WSB distribution system. During 1988, Cumberland purchased an average of 0.33 Mgal/d from Pawtucket WSB. The emergency interconnection with Lincoln was not used in 1988. Cumberland's third interconnection provides Lippitt ECA with their sole source of supply. During 1988, 0.02 Mgal/d was sold to Lippitt ECA. The data for water distributed to other public suppliers are presented in table 3.

Table 3.--Distribution of water among public suppliers in Cumberland, 1988

[Data from Cumberland Water Department and Pawtucket Water Supply Board. Withdrawal and delivery in million gallons per day (Mgal/d); M, metered; E, estimated]

Public supplier	Withdrawn in Cumberland and available for distribution	Purchased from Cumberland public suppliers	Sold to Cumberland public suppliers	Sold outside Cumberland	Distributed inside Cumberland
Cumberland Water Department	1.84 M	0.33 M	0.02 M	0	2.15 M
Pawtucket Water Supply Board	13.08 M	0	.33 M	[1]11.20 E	[2] 1.55 E
Lippitt Estates Community Association	0	.02 M	0	0	.02 M
Total distributed	14.92 M	.35 M	.35 M	11.20 E	3.72 E

[1]Includes 0.73 Mgal/d distributed through Pawtucket Water Supply Board's Cumberland distribution system to Massachusetts customers and 0.88 Mgal/d unaccounted water (estimated as 8 percent of the water distributed outside Cumberland).

[2]Includes 0.17 Mgal/d of unaccounted water (estimated as 8 percent of the water distributed inside Cumberland).

In the Pawtucket WSB system, water treated in the Mill Street treatment facility (1010) enters the distribution system (1011) at the plant. The treated ground water from wells 4 and 5 enters the distribution system at the wellheads. Most of Pawtucket WSB's treated water, 11.20 Mgal/d, is distributed outside of Cumberland. In addition, 1.55 Mgal/d is distributed to the southern part of Cumberland.

Cumberland WD has four storage tanks in the system: Coppermine (Tank 1) with a storage capacity of 3.3 Mgal, Palomino (Tank 2) with 3.4 Mgal, Sneech Pond (Tank 3) with 0.33 Mgal, and Thompson (Tank 4) with 0.75 Mgal. Total storage capacity is approximately 7.8 Mgal. Their locations are shown on figure 4. The Cumberland WD main distribution system parallels the major roads within the town. Water is pumped to the storage tanks and feeds by gravity to most of the customers. Pawtucket WSB maintains no storage tanks inside Cumberland.

Conveyance from Public Suppliers to Users

Estimates of the volume of water delivered by Cumberland WD to domestic, industrial, and commercial users (table 4) were developed by analyzing the total volume of water available for distribution (2.15 Mgal/d), monthly meter readings (large users), estimates of unmetered use from the utility or consultants, and annual meter readings (small users). The meters that are read monthly (termed "industrial" by Cumberland) recorded delivery of a total of 0.48 Mgal/d during 1988, of which 0.04 Mgal/d was delivered to large domestic users (listed in appendix 1), 0.39 Mgal/d to large industrial users (appendix 2), and 0.05 Mgal/d to large commercial users (appendix 3). Unmetered use includes leakage and water used for fire fighting and street cleaning. On the basis of data compiled by A.D. Little, Inc. (1989), unmetered use during 1988 was estimated at 0.41 Mgal/d, or 19 percent of total available water. The remaining 1.26 Mgal/d were delivered to small industrial, commercial, and domestic users.

The records of meters read annually were examined for meter size and customer names to develop estimates for the volume of water delivered to industrial, commercial, or domestic customers. The volume of water delivered to industrial users was estimated first because this group included the largest individual users. The list of large industrial users supplied by Cumberland WD was compared with the Rhode Island Department of Commerce's Directory of Manufacturers data base (DMDB). Most (95 percent) of the employees of industries listed in the DMDB within the Cumberland WD service area were employed by Cumberland WD's large industrial users. Assuming that a small number of industries were missing from the DMDB, an additional 0.06 Mgal/d (13 percent) was estimated to be delivered to the small industries, for a total industrial delivery of 0.45 Mgal/d.

There are many more small commercial users than large commercial users, so that the volume delivered to large and small commercial users was estimated to be approximately the same (approximately 0.05 Mgal/d), for a total commercial delivery of 0.10 Mgal/d. The deliveries to large domestic users (0.04 Mgal/d) were combined with the remaining 1.15 Mgal/d for total deliveries to domestic users of 1.19 Mgal/d. RIDOH data indicate that the population served by the Cumberland WD in 1988 was approximately 17,500. The calculated domestic per capita use during 1988 is 68 gal/d. According to the Cumberland WD, there were 5,350 active service connections in 1988.

Table 4.--Distribution of water withdrawn for public supply in Cumberland, 1988

[Data from the Rhode Island Department of Health, Cumberland Water Department, and Pawtucket Water Supply Board. E, estimated; M, metered; ECA, Estates Community Association; WD, Water Department; WSB, Water Supply Board]

Public supplier	Distribution, in million gallons per day								Number of service connections	Estimated population served	Domestic per capita use (gal/d)
	Total	Domestic		Industrial		Commercial		Unmetered			
		Large	Small	Large	Small	Large	Small				
Cumberland WD	2.15 M	0.04 M	1.15 E	0.39 M	0.06 E	0.05 M	0.05 E	0.41 E	5,350	17,500	68
Pawtucket WSB	[1]1.55 E	.02 M	1.11 E	[1].05 M	.10 E	.05 M	.10 E	.12 E	2,456	8,170	138
Lippitt ECA	.02 M	0	.02 M	0	0	0	0	0	100 E	300	67
Total or average	3.72 E	.06 M	2.28 E	.44 M	.16 E	.10 M	.15 E	.53 E	7,906	25,970	90
Percentage of total water distributed	100	2	61	12	4	3	4	14			

[1] Excludes the 0.73 Mgal/d distributed through Pawtucket Water Supply Board's Cumberland distribution system to Massachusetts customers.

Pawtucket WSB also keeps records on customers in Cumberland with an account number coded for Cumberland; however, two large industries with the Cumberland code, North East Cable Corp. and Crown Yarn and Dye Co. are actually in Attleboro, Mass. The volume of water delivered to these two industries, 0.73 Mgal/d, accounted for 86 percent of the 0.85 Mgal/d recorded as being delivered by Pawtucket WSB to the large customers in the Cumberland service area. Subsequent discussion of distribution in Cumberland excludes the 0.73 Mgal/d delivered to Massachusetts.

Estimates of deliveries by Pawtucket WSB to domestic, industrial, and commercial users in the Cumberland area (table 4) were developed by analyzing the total volume of water available for distribution (1.55 Mgal/d), quarterly meter readings (large users), estimates of unmetered use, and the biannual meter readings (small users). The meters that are read quarterly (termed "industrial" by Pawtucket) recorded a total delivery of 0.12 Mgal/d, of which 0.02 Mgal/d was delivered to large domestic users (listed in appendix 1), 0.05 Mgal/d to large industrial users (appendix 2), and 0.05 Mgal/d to large commercial users (appendix 3). Unmetered water use during 1988 was estimated at 0.12 Mgal/d, or 7.7 percent of total water available for distribution, based on data obtained from the Pawtucket WSB. The remaining 1.31 Mgal/d was delivered to small domestic, industrial, and commercial users.

During 1988, the total volume of water delivered by Pawtucket WSB to large users in Cumberland amounted to a smaller percentage (8 percent) of the total volume of water distributed than Cumberland WD (22 percent). Because these are the only reliable data, the estimates of the remaining delivery to industrial, commercial, and domestic users by Pawtucket WSB are less reliable. The volume delivered to large industrial users, 0.05 Mgal/d, was doubled to estimate the volume delivered to small industrial users, 0.10 Mgal/d, for a total of 0.15 Mgal/d. The volume delivered to large commercial users, 0.05 Mgal/d, was also doubled, to 0.10 Mgal/d, for a total of 0.15 Mgal/d. The remaining deliveries, 1.11 Mgal/d estimated as delivered to small domestic users, were combined with large domestic deliveries, 0.02 Mgal/d, for a total of 1.13 Mgal/d. According to the U.S. Bureau of Census (1981), 92.5 percent of the households in Cumberland were on public supply in 1980. In 1990, 91.4 percent of the households in Cumberland were on public supply (Rhode Island Division of Planning, 1992). Interpolating between the two values, 91.6 percent of households in Cumberland were on public supply in 1988. Applying this percentage to the 1988 population (28,350) indicates approximately 25,970 residents were on public supply. Subtracting the population supplied by other public suppliers, the 1988 population served by Pawtucket WSB was estimated as 8,170. The calculated domestic per capita use for the service area during 1988 is 138 gal/d. According to the Pawtucket WSB, there were 2,456 active service connections in 1988.

The third public supplier, Lippitt ECA, serves approximately 300 people and is wholly supplied by Cumberland WD through a metered connection. Cumberland WD sold 0.02 Mgal/d to this system in 1988. Lippitt ECA has a 0.03-Mgal-capacity storage tank. Distribution is all residential, with an estimated per capita use of 67 gal/d.

Estimated per capita use for domestic users served by Cumberland WD and Lippitt ECA during 1988 were 68 gal/d and 67 gal/d, respectively. These estimates correlate closely with per capita values for domestic deliveries by public suppliers in 1985 estimated in a study of Middlesex and Monmouth Counties, N. J. (unpublished data on file at the U.S. Geological Survey office in West Trenton, N. J.). Estimated per capita use for domestic users served by Pawtucket WSB were 138 Mgal/d, about twice that of Cumberland WD and Lippitt ECA. This high value

most likely results from incorrect identification of deliveries outside Cumberland as deliveries within Cumberland, from an unusually high number of meter-reading errors, or may result from meters that registered too high a volume (meter overregistration).

Consumptive use in Cumberland during the withdrawal, treatment, and distribution processes occurs when water evaporates from open storage (reservoirs or tanks), during treatment (from settling ponds), or from conveyance systems. Very little (less than 0.01 Mgal/d) consumptive use occurs during these processes because treated water in Cumberland is stored in closed tanks. During distribution, significant quantities of water may be "unaccounted for" or leaked out of the system; however, leakage is not considered consumptive use because the water may be available for reuse from the ground-water and surface-water systems. In summary, all consumptive use that occurs during supply processes in Cumberland is through evaporation from surface-water bodies.

Self-Supply Withdrawal

Self supply incorporates all users who withdraw their water directly from surface-water or ground-water sources. The major use categories of withdrawal for self supply in Cumberland are domestic, industrial, and commercial. Withdrawal for self supply is summarized in table 5. Major users are listed in the table. Minor users that withdrew less than 0.01 Mgal/d were aggregated by use category and aquifer.

Domestic self supply consists of withdrawal for drinking water by and for individual housing units, which include individual houses, apartments, attached houses, nursing homes, a novitiate, or any place where people reside and are included in a census survey. No single domestic withdrawal greater than 0.01 Mgal/d was identified in Cumberland.

Estimates of the volume of self-supplied withdrawal were based on the percentage of households that were self-supplied and the average per capita use. Subtracting the estimated number of residents on public supply in 1988 (25,970 people) from the total 1988 population (28,350) indicated that approximately 2,380 residents withdrew their own water. Estimated per capita use for Cumberland WD was 68 gal/d; for Pawtucket WSB, 138 gal/d; and for Lippitt ECA, 67 gal/d (table 4). The Pawtucket WSB value was considered too high, so the other per capita values were used and rounded to 70 gal/d as the self-supply per capita use. Domestic self supply was estimated to be 0.17 Mgal/d (self-supplied population multiplied by per capita use).

Most of the self-supplied population lives in the northern part of Cumberland or along the ridge that separates the two subbasins. Examination of data on the extent, depth, and yields of the aquifers underlying these areas led to an estimate for withdrawal from the four aquifers: 40 percent from till, 40 percent from bedrock, 15 percent from the Abbott Run ground-water reservoir, and 5 percent from Blackstone Valley ground-water reservoir. No domestic withdrawal was from surface-water sources.

Commercial withdrawal includes water withdrawn for drinking water or sanitary facilities in restaurants, offices, shopping centers, or recreational areas, and in buildings that use water for heating or air conditioning. Although the RIDOH has data on six self-supplied commercial users (noncommunity suppliers) in Cumberland (three restaurants, two campgrounds, and one visitors center), none exceeds 0.01 Mgal/d; therefore, these six users are included in the aggregated usage. Estimates of the volume of commercial withdrawal during 1988 were based on the assumption

Table 5.--Withdrawal of water for self supply in Cumberland, 1988

[Data from Cumberland Water Department, Pawtucket Water Supply Board, and Blackstone Valley District Commission. Use category and user: Aggregate, combined withdrawals of all users who withdrew less than 0.01 million gallons per day during 1988 in each use category. Source of water: Bedrock aquifer refers to crystalline and undifferentiated sedimentary-rock aquifers that underlie glacial deposits. Withdrawal: Column may not add up to totals because of independent rounding. Mgal/d, million gallons per day; GWR, ground-water reservoir; <, actual value is less than value shown]

Use category and user	Source of water	Withdrawal (Mgal/d)
	DOMESTIC	
Aggregate	Blackstone GWR	0.01
Aggregate	Abbott Run GWR	.02
Aggregate	Bedrock aquifer	.07
Aggregate	Till aquifer	.07
Domestic total		.17
	INDUSTRIAL	
Electroformax Laboratories, Inc.	Blackstone GWR	.02
Peterson Puritan, Inc. [1]	Blackstone GWR	.03
Aggregate	Blackstone GWR	.01
Aggregate	Abbott Run GWR	.01
Aggregate	Bedrock aquifer	.01
Aggregate	Till aquifer	<.01
Industrial total		.08
	COMMERCIAL	
Aggregate	Blackstone GWR	<.01
Aggregate	Abbott Run GWR	<.01
Aggregate	Bedrock aquifer	.01
Aggregate	Till aquifer	.01
Commercial total		.02
	LIVESTOCK	
Aggregate	Till aquifer	<.01
Livestock total		<.01
	IRRIGATION	
Aggregate	Till aquifer	<.01
Irrigation total		<.01
Total		.28

[1] Withdrawn and released to wastewater-collection system as part of ground-water contamination remediation.

that the ratio between self supply and public supply for domestic use (0.17/2.34 or 7.3 percent) was the same for commercial use. This assumption is based on the observation that the number and distribution of small commercial establishments generally parallels population distributions (Robert R. Pierce, U.S. Geological Survey, oral commun., 1989). Consequently, 7.3 percent of public supply for commercial use (0.25 Mgal/d; table 4) results in a commercial self-supply value of 0.02 Mgal/d.

As with domestic withdrawal, commercial withdrawal was concentrated in the northern part of Cumberland and along the central ridge. Because commercial withdrawal was considered small, half of the withdrawal was estimated to be from wells completed in till and the other half from wells completed in bedrock. No commercial surface-water withdrawal was identified.

Industrial withdrawal includes water used for fabrication, processing, washing, and cooling in such industries as chemical and plastic, textile, wood-product, nonferrous-metal, and jewelry manufacturing. Major self-supplied industries were identified by use of Blackstone VDC data and Rhode Island Pollutant and Discharge Elimination System (RIPDES) permit data. Industries that were listed with Blackstone VDC (appendix 5) or had RIPDES permits (table 9) but were not on the customer lists for Cumberland WD or Pawtucket WSB (appendix 2) were assumed to be self-supplied. Two major industries that were at least partially self-supplied were Peterson Puritan, Inc. and Electroformax Laboratories, Inc. Total withdrawal for these industries during 1988 was estimated at 0.05 Mgal/d on the basis of data obtained from the Blackstone VDC (table 8). Peterson Puritan, Inc. and Electroformax Laboratories, Inc., are located along the Blackstone River in an industrial area that is also served by the Cumberland WD. Both industries have wells in the Blackstone ground-water reservoir.

Total withdrawal for Electroformax Laboratories, Inc., Peterson Puritan, Inc., and publicly supplied industries was estimated to account for approximately 95 percent (0.65 Mgal/d) of all industrial use. The withdrawal by industries using less than 0.01 Mgal/d was estimated at 0.03 Mgal/d. Industrial withdrawal requires more water than can be produced from a well completed in till. Therefore, industrial ground-water withdrawal was estimated as one-third from wells completed in bedrock, one-third from wells completed in the Blackstone ground-water reservoir, and one-third from wells completed in the Abbott Run ground-water reservoir. No industrial surface-water withdrawal was identified.

Other uses of self-supplied water in Cumberland include livestock watering and irrigation. No individual livestock farms or irrigators withdrew more than 0.01 Mgal/d during 1988. Withdrawal for livestock watering and irrigation were each estimated at less than 0.01 Mgal/d, primarily from till aquifers.

Overview

After all the supply water-use data (withdrawal, water treatment, and distribution) have been collected, analyzed, and entered into the water-use data base, the data can be retrieved in various ways to summarize the effect of supply on the water resources. This overview concentrates on which resources are affected by the withdrawal, how most of the water is used in the area, and how much of the water becomes unavailable in the area through exportation and consumptive use. Table 6 summarizes withdrawal in Cumberland, and figure 5 displays it graphically. In

Cumberland, surface-water withdrawal (13.42 Mgal/d) accounted for 87 percent of all withdrawal; ground-water withdrawal (1.97 Mgal/d) accounted for the remaining 13 percent (fig. 5*A*).

Table 6.--Water withdrawal summary for Cumberland, 1988

[Data from Cumberland Water Department, Pawtucket Water Supply Board, and Blackstone Valley District Commission. Withdrawal in million gallons per day. Bedrock refers to crystalline and undifferentiated sedimentary rock aquifers that underlie glacial deposits. Other includes livestock watering and irrigation. GWR, ground-water reservoir; <, less than; --, no data or not applicable]

	Public supply	Domestic	Indus-trial	Commer-cial	Other	Ground-water total	Surface-water total	Subbasin total
BLACKSTONE RIVER SUBBASIN								
Surface water	0.70	--	--	--	--	--	0.70	
Ground water								
Blackstone GWR	.86	0.01	0.06	<0.01	--	0.93	--	
Bedrock	--	.03	<.01	.01	--	.04	--	
Till	--	.03	<.01	<.01	<.01	.03	--	
Blackstone totals	1.56	.07	.06	.01	<.01	1.00	.70	1.70
ABBOTT RUN SUBBASIN								
Surface water	12.72	--	--	--	--	--	12.72	
Ground water								
Abbott Run GWR	.83	.02	.01	<.01	--	.86	--	
Bedrock	--	.04	.01	<.01	--	.05	--	
Till	--	.04	<.01	.01	.01	.06	--	
Abbott Run totals	13.55	.10	.02	.01	.01	.97	12.72	13.69
Totals	15.11	.17	.08	.02	.01	1.97	13.42	15.39
Total exported from Cumberland								11.20

Total withdrawal within the Blackstone River subbasin (1.70 Mgal/d) accounted for 11 percent of withdrawal in Cumberland. Withdrawal from the Blackstone River subbasin was about 12 percent of the estimated volume available to surface-water and ground-water systems from average annual recharge (13.65 Mgal/d). Withdrawal in the Abbott Run subbasin totaled 13.69 Mgal/d, primarily because of withdrawal by the Pawtucket WSB. Withdrawal from the Abbott Run subbasin was about 70 percent of the estimated volume available to surface-water and ground-water systems from average annual recharge (19.65 Mgal/d).

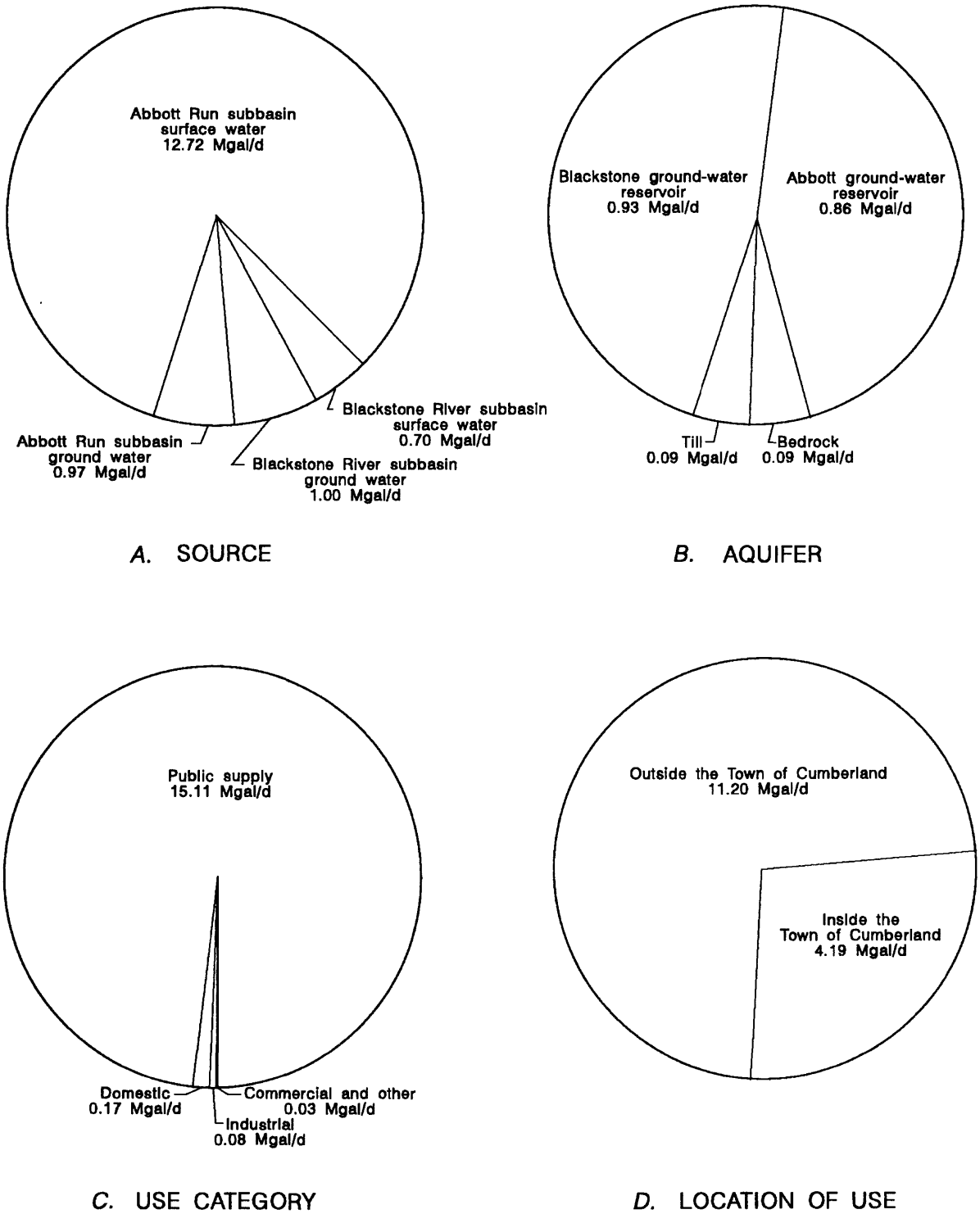


Figure 5.--Withdrawal of water by (*A*) source, (*B*) aquifer, (*C*) use category, and (*D*) location of use in Cumberland, Rhode Island. (Sources of data are listed in table 1.)

Withdrawal from the Blackstone ground-water reservoir (0.93 Mgal/d) accounted for about 47 percent of ground-water withdrawal in Cumberland (fig. 5*B*), primarily because of withdrawal by the Cumberland WD. Withdrawal from Abbott Run ground-water reservoir (0.86 Mgal/d) accounted for about 44 percent of ground-water withdrawal in Cumberland, because of withdrawal by both Cumberland WD and Pawtucket WSB. The remaining 9 percent of ground-water withdrawal in Cumberland was from bedrock (0.09 Mgal/d) and till aquifers (0.09 Mgal/d).

Withdrawal for public supply (15.11 Mgal/d) accounted for 98 percent of all withdrawal in Cumberland (fig. 5*C*). Domestic withdrawal (0.17 Mgal/d) accounted for 1 percent; industrial withdrawal (0.08 Mgal/d) for 0.5 percent; and commercial (0.02 Mgal/d), livestock (<0.01 Mgal/d), and irrigation (<0.01 Mgal/d) withdrawal (table 5) accounted for the remaining 0.5 percent. No water is imported into Cumberland for use; however, 73 percent of the total withdrawal (11.20 Mgal/d) was exported from Cumberland (fig. 5*D*) by the Pawtucket WSB. Consumptive use during supply was less than 0.01 Mgal/d.

ESTIMATION OF WATER USE BY CATEGORY

Water use, in a restrictive sense, refers to water that is actually used for a specific purpose, such as for domestic purposes, irrigation, or industrial processing. Water use in this restrictive sense is one of the six main processes of the broader definition of water use that pertains to human interaction with and effects on the hydrologic cycle and that includes elements such as water withdrawal, distribution, consumptive use, wastewater collection, and return flow. The user can be an individual household, shopping center, or industry, or the user can be an aggregate, such as a community of users within a surface-water basin. All activity before use involves supplying the user with water; all activity after use involves disposing of wastewater.

Three components constitute water use in the restricted sense--**total water received** by users, consumptive use, and **total water released** by users. The total water received by a user is the sum of all water withdrawn and(or) delivered to a user. The total water received by a group of users, such as in a town, is the sum of all water withdrawn or imported into the town. Consumptive use is water that evaporates, is incorporated into a product during use, or is discharged into brackish or saline water after use (assuming that the water was withdrawn as freshwater). Total water released by a user is the sum of all water that is released from the point of use (1) to an onsite wastewater-treatment facility, (2) to a collection system for offsite wastewater treatment, or (3) as return flow. Total water released by a group of users, such as a town, is the sum of all water that is released as return flow or exported for treatment outside the town.

In general, the volume of use is equal to the total volume of water received. The volume of use also equals the sum of consumptive use plus the total volume of water released. If measured or estimated values are placed into the equation

water use = total water received = consumptive use + total water released,

estimates can be developed for the remaining components. For example, if 100 Mgal/d was delivered to a factory, 10 Mgal/d was incorporated into the product, and 80 Mgal/d was discharged into the wastewater-collection system, then 10 Mgal/d could be assumed to have evaporated. Conveyance losses or gains and unmetered use complicate the water-use equation. For instance, conveyance losses need to be subtracted from withdrawal before it can equal use. In

this section, water use is discussed by use category and illustrated in figure 6 by indicating areas where domestic, industrial, commercial, and agricultural use occurs in Cumberland. This illustration is based on a land-use map of Cumberland and displays areas where the indicated category of use predominates.

Domestic

Domestic use is the largest use in Cumberland, accounting for about two-thirds of all water used. The total water received by domestic users in 1988 was approximately 2.51 Mgal/d (table 7). As figure 6 illustrates, most of the domestic use in Cumberland occurs in the southern tip, in the west along Highway 122 (which roughly borders the Blackstone River), and in the east along Highway 114, near the Massachusetts border, especially just south of the Arnold Mills Reservoir. Two major domestic users (more than 0.01 Mgal/d) in Cumberland, Lippitt ECA and Maplewood Condominiums, receive water from Cumberland WD (table 8).

During 1988, Cumberland WD delivered 1.19 Mgal/d to 17,500 people, Pawtucket WSB delivered 1.13 Mgal/d to 8,170 people, and Lippitt ECA delivered 0.02 Mgal/d to 300 people, for a total of 2.34 Mgal/d delivered to 25,970 people (table 4). The large domestic users (as defined by the individual utility) who received water from public suppliers during 1988 are listed in appendix 1. These users represent only 2 percent of public supply for domestic use. Self supply for domestic use was estimated at 0.17 Mgal/d (table 5) among 2,380 people.

In the New England States, the coefficient for domestic consumptive use is 15 percent (Solley and others, 1993), primarily because of evaporation during lawn and garden watering, during car and sidewalk washing, and from pools. Application of this coefficient to Cumberland yields a consumptive-use value of 0.38 Mgal/d for 1988 (table 7).

Total water released from domestic use through wastewater collection and septic-system discharges during 1988 was equal to the total water received (2.51 Mgal/d) minus consumptive use (0.38 Mgal/d), or 2.13 Mgal/d. According to the U.S. Bureau of Census (1981), 27.2 percent of the households in Cumberland discharged to public wastewater-collection systems in 1980. In 1990, 48.4 percent of households discharged wastewater to wastewater-collection systems (Rhode Island Division of Planning, Department of Administration, 1992). Interpolating between these two values yields 44.2 percent of the households were on public wastewater collection systems in 1988. Multiplication of the percentage of domestic users that are self-disposed (55.8 percent) with the 1988 population (28,350) results in approximately 15,820 people who dispose their wastewater into private septic systems.

Domestic self-supplied per capita use is 70 gal/d; however, the average per capita use from public supply is 90 gal/d (table 4). Because 90 percent of the people on septic systems are also on public supplies, 90 gal/d was used to determine the volume of water received by domestic users who disposed of wastewater by way of septic systems. Application of the 85 percent nonconsumptive use coefficient to 90 gal/d yields 77 gal/d, which is multiplied by the population on septic systems to yield 1.22 Mgal/d. Subtracting 1.22 Mgal/d from the total releases of 2.13 Mgal/d leaves 0.91 Mgal/d discharged into the wastewater-collection system.

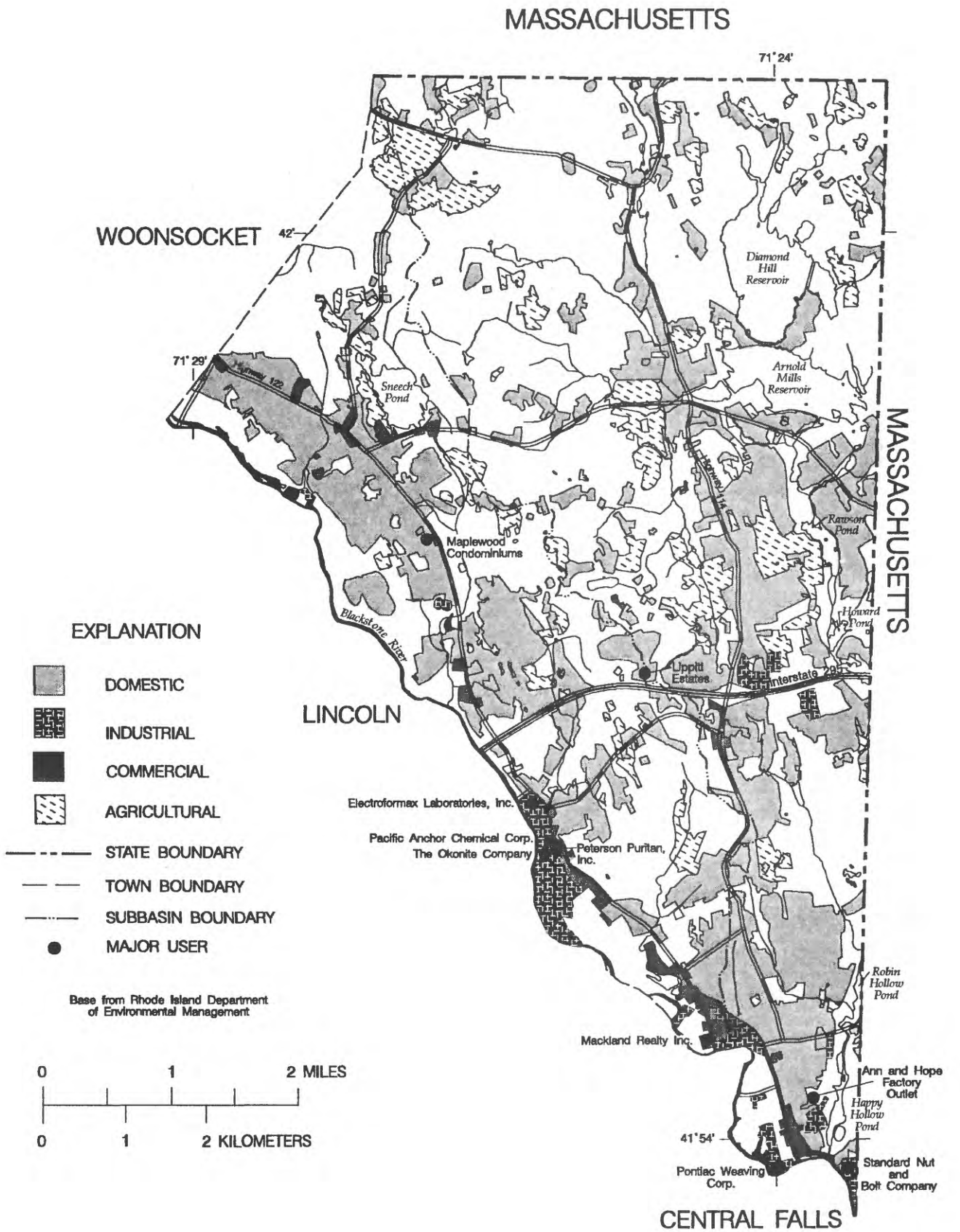


Figure 6.--Categories of water use in Cumberland, Rhode Island. (Sources of data are listed in table 1.)

Table 7.--Water-use summary for Cumberland, 1988

[Data from Rhode Island Department of Environmental Management, Cumberland Water Department, Pawtucket Water Supply Board, and Blackstone Valley District Commission. Use in million gallons per day; gw, ground water; sw, surface water; --, no data available or not applicable; <, less than]

Processes	Public supply	Domestic	Industrial	Commercial	Agriculture-livestock	Irrigation-agricultural	Unmetered	Total
			SUPPLIED WATER					
Withdrawn water	15.11	0.17	0.08	0.02	<0.01	<0.01	--	15.39
Exported water[1]	11.20	--	--	--	--	--	--	11.20
Distributed water	--	2.34	.60	.25	--	--	.53	--
Treatment of water	.19	--	--	--	--	--	--	--
Total water received in Cumberland[2]	[3] 3.91	2.51	.68	.27	<.01	<.01	.53	4.19
			CONSUMPTIVE USE					
Evaporation	--	.38	.03	.02	<.01	<.01	--	.43
Product incorporation	--	--	<.01	--	<.01	<.01	--	--
Total consumptive use in Cumberland[3]	--	.38	.03	.02	<.01	<.01		.43
			DISPOSED WATER					
WW collection system exported from Cumberland	--	.91	.39	.11	--	--	.32	1.73
SW return flow	.19	--	.23	--	--	--	--	.42
Direct gw return flow	--	--	.01	--	<.01	--	.22	.23
Septic-system gw return flow	--	1.22	.02	.14	--	--	--	1.38
Total water released in Cumberland[3]	.19	2.13	.65	.25	<.01	--	.54	3.76

[1]Subtracted from withdrawn water.

[2] Meter-reading errors and rounding may prevent "Total Water Received" from equaling "Total Consumptive Use" plus "Total Water Released."

[3] Total water distributed for domestic, industrial, commercial, and unmetered uses, plus 0.19 Mgal/d used during water treatment. This value is not included in "Total" column for "Supplied Water."

An alternative method for calculation of the volume disposed into septic systems instead of wastewater-collection systems is to multiply the volume of unconsumed domestic water (2.13 Mgal/d) by 55.8 percent for the septic-system disposal (1.19 Mgal/d) and by 44.2 percent for public-system disposal (0.94 Mgal/d). The difference between results of the two methods is approximately 2 percent.

Industrial

Industrial use is the second largest use in Cumberland, constituting approximately 15 percent of all water used. Total water received by industries during 1988 was approximately 0.68 Mgal/d. Most of the industrial use is in the west along the Blackstone River, in Cumberland's southern tip, and at the intersection of Highway 114 and Interstate 295 (fig. 6). The six major industrial users in Cumberland are Electroformax Laboratories, Inc., The Okonite Company, Pacific Anchor Chemical Corp., Peterson Puritan, Inc., Pontiac Weaving Corp., and Standard Nut and Bolt Company (table 8).

During 1988, Cumberland WD delivered 0.45 Mgal/d and Pawtucket WSB delivered 0.15 Mgal/d for a total of 0.60 Mgal/d to industrial customers. The large industrial users who received water from public suppliers during 1988 are listed in appendix 2. These users represent about three-quarters of public supply for industrial use. Self-supplied industrial use was about 0.08 Mgal/d (table 5).

In Cumberland, most of the industrial water use is for noncontact cooling. Evaporation was estimated by the industries to account for 0.03 Mgal/d during 1988. Less than 0.01 Mgal/d was incorporated into the product (table 7).

The total volume of water released by industrial users was 0.65 Mgal/d during 1988. Return flow to surface water was 0.23 Mgal/d. Direct ground-water return flow was estimated to be 0.01 Mgal/d, whereas the remaining 0.41 Mgal/d was released to the Blackstone VDC and to septic systems (table 7). The Blackstone VDC wastewater-collection system received approximately 0.39 Mgal/d from industrial users (appendix 2). Septic-system discharges were estimated at 0.02 Mgal/d.

Commercial

Commercial use is the third largest use in Cumberland constituting approximately 6 percent of all water used. During 1988, total water received for commercial use was approximately 0.27 Mgal/d (table 7). Commercial use in Cumberland occurs primarily along major roads (fig. 6). The two major commercial users are Ann and Hope Factory Outlet and Mackland Realty, Inc. (table 8).

Cumberland WD delivered 0.10 Mgal/d and Pawtucket WSB delivered 0.15 Mgal/d for a total of 0.25 Mgal/d to commercial users (table 4). The large commercial users who received water from public suppliers during 1988 are listed in appendix 3. These users represent almost one-half the public supply for commercial use. Self-supplied commercial use was about 0.02 Mgal/d (table 5).

Table 8.--Major waters users in Cumberland, 1988

[Data from Rhode Island Department of Environmental Management, Cumberland Water Department, Pawtucket Water Supply Board, and Blackstone Valley District Commission. Water use in million gallons per day. Blackstone GWR, Blackstone River ground-water reservoir; Blackstone R, Blackstone River; BVDC, Blackstone Valley District Commission; CWD, Cumberland Water Department; Evap, evaporation; PI, product incorporation; PWSB, Pawtucket Water Supply Board; Septic, septic system; <, less than. Meter-reading errors and rounding prevent Total Received from equaling Consumptive Use plus Total Released]

Major user	Total received		Consumptive use		Total released	
	Source	Rate	Type	Rate	Destination	Rate
DOMESTIC USERS						
Lippitt Estates Community Association Lippitt Avenue	CWD	0.02	Evap	<0.01	Septic	0.02
Maplewood Condominiums 2970 Mendon Road	CWD	.01	Evap	<.01	BVDC	.01
INDUSTRIAL USERS						
Electroformax Laboratories, Inc. 1 Front Street	Wells	0.02	Evap	<0.01	Blackstone R Septic	0.02 <.01
The Okonite Company 111 Martin Street	CWD	.12	Evap	<.01	Blackstone R Blackstone GWR	.12 <.01
Pacific Anchor Chemical Corp. 1224 Mendon Road	CWD	.11	Evap	<.01	Blackstone R Blackstone GWR BVDC	.10 <.01 .01
Peterson Puritan, Inc. Martin Street	CWD Wells	.12 .03	Evap & PI	.03	BVDC	.13
Pontiac Weaving Corp. Meeting Street	PWSB	.02	Evap	<.01	BVDC	.02
Standard Nut and Bolt Company 49 Abbott Street	PWSB	.02	Evap	<.01	BVDC	.02
COMMERCIAL USERS						
Ann and Hope Factory Outlet 47 Cross Street	PWSB	0.02	Evap	<0.01	Septic	0.02
Mackland Realty, Inc. 52-60 Mendon Road	PWSB	.01	Evap	<.01	BVDC	.02

The percentage of commercial consumptive use in Cumberland is less than the percentage of domestic consumptive use because commercial use does not include as much lawn and garden watering, car or sidewalk washing, or as many pools. Applying a coefficient of 8 percent to Cumberland yields a consumptive use of 0.02 Mgal/d during 1988 (table 7).

Total water released by commercial users to wastewater-collection and septic systems was estimated by the alternative method used for estimating the total volume of water released by domestic users. The volume of unconsumed commercial water (0.25 Mgal/d) was multiplied by 55.8 percent to obtain the volume released to the septic system, 0.14 Mgal/d, and by the 44.2 percent to obtain the volume released to wastewater-collection systems, 0.11 Mgal/d.

Other Use Categories

Unmetered use from Cumberland WD was estimated to be 0.41 Mgal/d and from Pawtucket WSB, 0.12 Mgal/d, for a total of 0.53 Mgal/d during 1988 (table 4). Although this volume represents approximately 14 percent of total use in Cumberland, unmetered use is not considered one of the three major use categories because it is composed of a variety of different uses. Unmetered use includes water used for fire fighting, hydrant flushing, sanitation, and parks; however, the largest component of unmetered use is unaccounted for use. Unaccounted for use is undetected leakage from supply lines, unauthorized use, and meter readings that are too low. Conversely, it is decreased by meter readings that are too high. Because of these variables, unmetered use tends to be a collection of unreconciled meter readings.

Other uses of water in Cumberland include water treatment, livestock, and irrigation. Water used for backwashing filters during water treatment was estimated at 0.19 Mgal/d, all of which was returned to surface water (table 2). Withdrawal for livestock watering was estimated at less than 0.01 Mgal/d during 1988 (table 5), of which 80 percent was consumptive use; approximately 60 percent was evaporated and 20 percent was incorporated into the animals. The remaining 20 percent was returned to the ground-water system. Irrigation withdrawal was estimated at less than 0.01 Mgal/d; virtually all was consumptive use, primarily loss to evaporation.

Overview

The use overview presents data on how water received by Cumberland users was used, how much consumptive use occurred during use, and what happened to the water after it was used. The total volume of water received by users in Cumberland was 4.19 Mgal/d during 1988 (table 7, fig. 7). Domestic use (2.51 Mgal/d) accounted for 60 percent, industrial use (0.68 Mgal/d) for 16 percent, and commercial use (0.27 Mgal/d) accounted for 6 percent. Unmetered use (0.53 Mgal/d), which includes unaccounted for water, amounted to 13 percent. Water used in backwashing filters during water treatment (0.19 Mgal/d) accounted for 4 percent. Use by livestock and irrigation (<0.01 Mgal/d) were less than 1 percent.

Public supply provided 93 percent of domestic use, 88 percent of industrial use, and 93 percent of commercial use. Unmetered use and water used during water treatment were entirely from public supplies. Livestock and irrigation uses were entirely self-supplied.

Consumptive use was 0.43 Mgal/d, of which evaporation (approximately 0.43 Mgal/d) accounted for 99 percent. In this report, evaporation includes water that evapotranspires from irrigated crops or is transpired by humans or domestic animals. The remaining 1 percent was estimated to be incorporated into manufactured products, livestock, or crops.

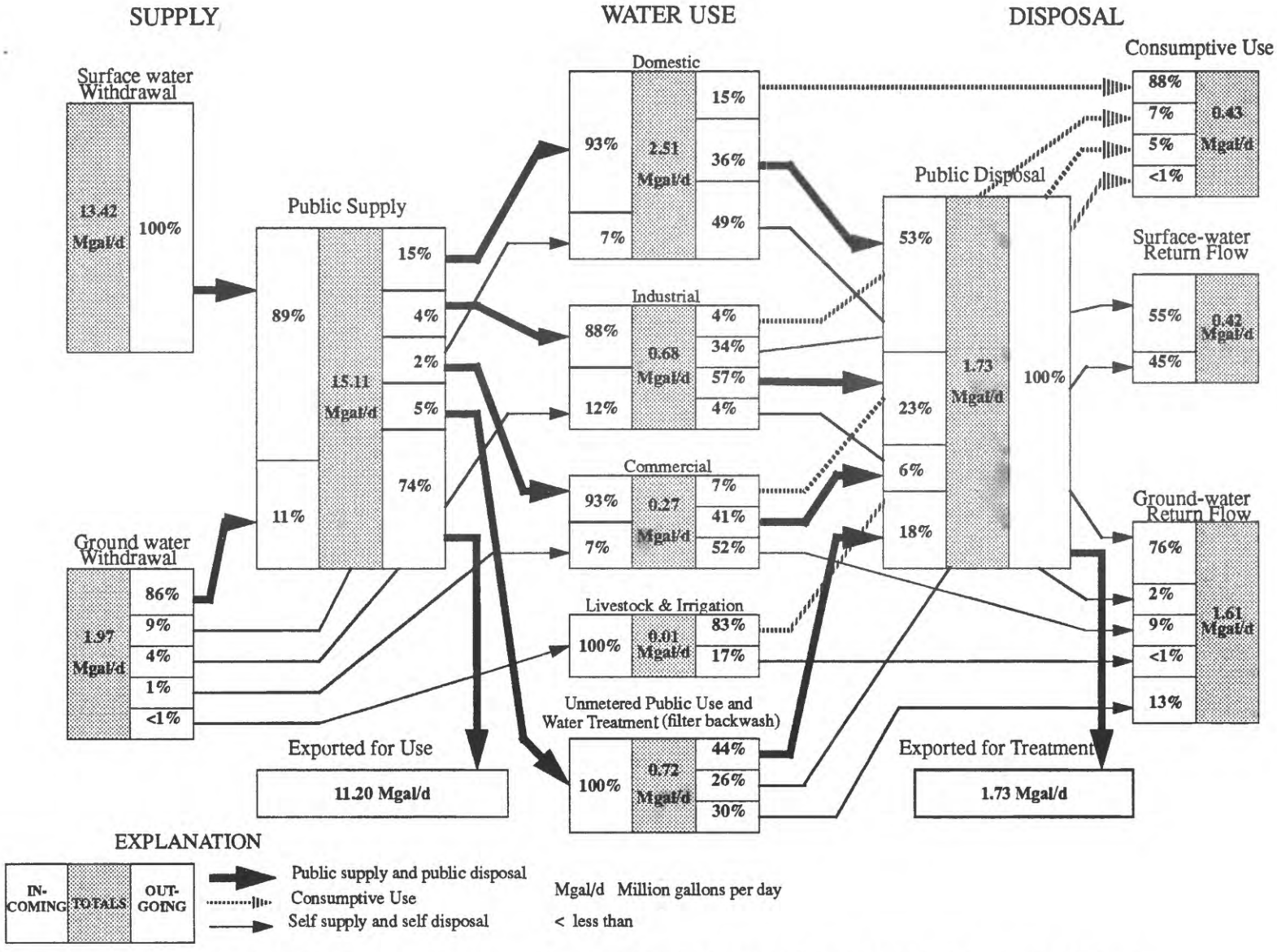


Figure 7.--Water-use summary for Cumberland, Rhode Island, 1988. (Sources of data are listed in table 1. Percentages have been rounded.)

The volume of water released by Cumberland users to public wastewater-collection systems or returned to the hydrologic system was estimated at 3.76 Mgal/d during 1988. Releases and returns by domestic users (2.13 Mgal/d) accounted for 57 percent, by industrial users (0.65 Mgal/d) 17 percent, and by commercial users (0.25 Mgal/d) 7 percent. Unmetered releases into the Blackstone VDC wastewater-collection system or leaked to ground water, 0.54 Mgal/d, represented 14 percent. Return of water used in backwashing filters (0.19 Mgal/d) accounted for 5 percent.

Disposal of wastewater remaining after consumptive use by way of public facilities accounted for 43 percent of domestic use, 60 percent of industrial use, and 44 percent of commercial use. About 59 percent of unmetered use, 0.32 Mgal/d, was estimated to have been discharged into wastewater collection systems. All water used for livestock, irrigation, and backwashing filters was disposed of by the users.

ESTIMATION OF WASTEWATER COLLECTION AND RETURN FLOW

Three of the six water-use processes are involved in disposing of water after use: wastewater-collection conveyance, wastewater treatment, and return flow. Wastewater collection and return flow are the critical disposal processes. Wastewater treatment is included as a disposal process because it provides the link between wastewater collection and return flow and includes water withdrawal when freshwater is required during treatment or consumptive use when evaporation occurs during treatment. Disposal in Cumberland, including RIPDES return-flow points, wastewater-treatment facilities, and the areal extent of the Blackstone VDC wastewater-collection system, is shown in figure 8.

Public Disposal

Public disposal consists of wastewater collected from users, treatment, and release as return flow to surface and ground water. The term "public disposal" is used because the public is being served, not because the entity collecting, treating, and discharging the water is publicly owned.

Wastewater-Collection Conveyance

Wastewater-collection conveyance, the first of three processes included in disposal, is the process of conveying wastewater, which also may include storm runoff, through a wastewater-collection system (sewer system) to a wastewater-treatment facility. In Cumberland, wastewater collection served approximately 12,530 people or 44.2 percent of the population during 1988 through two interconnected systems. The Cumberland Sewer Department operates and maintains the individual service connections and the feeder lines that connect into main interceptors. The Blackstone VDC owns, maintains, and meters the flow through the main interceptors. Blackstone VDC interceptors serve not only Cumberland but also several other communities. Blackstone VDC monitors flow through 10 interceptors in the Blackstone River valley, 7 of which are in the town of Cumberland (fig. 8). Blackstone VDC also calculates flow contributed by each community.

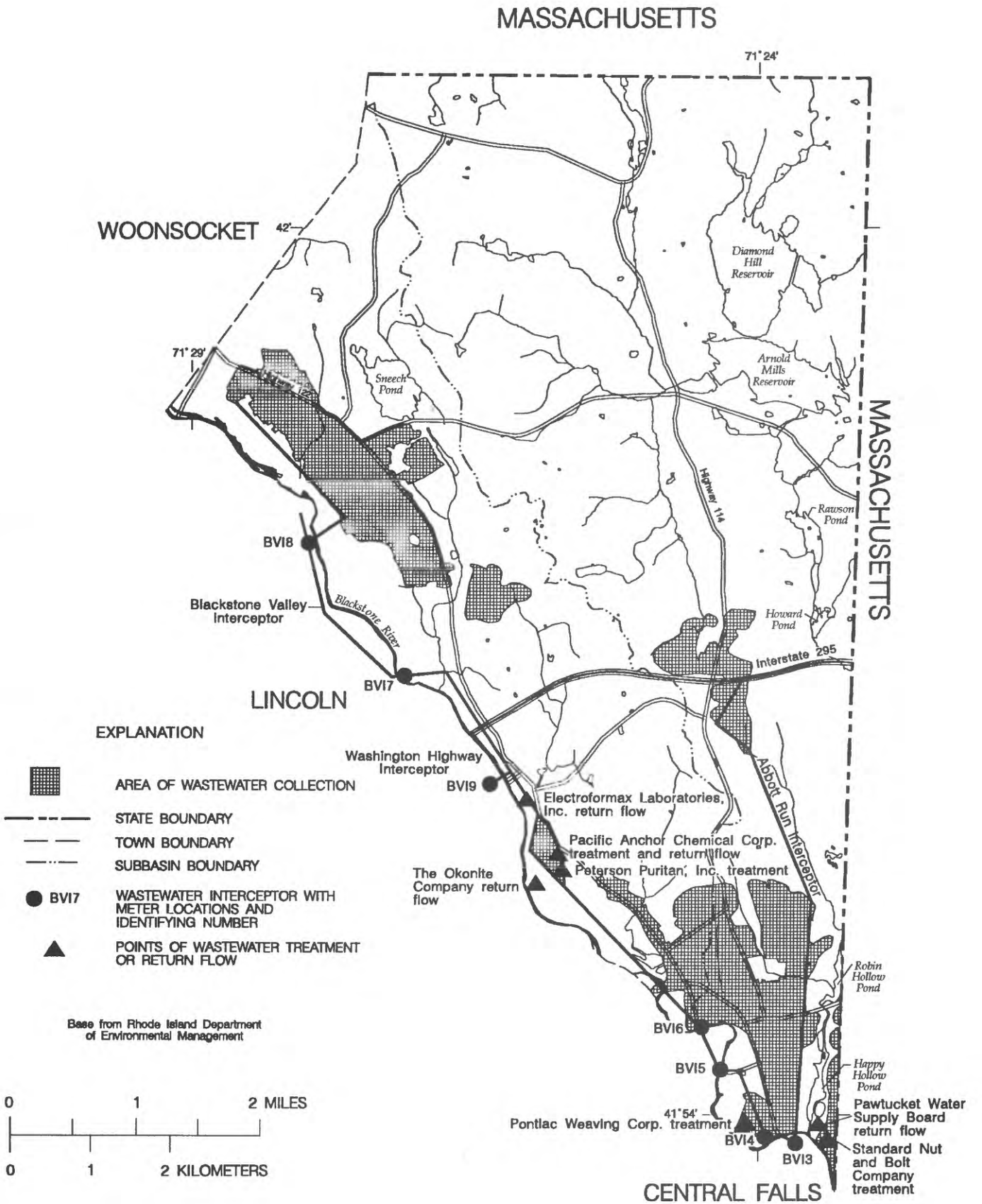


Figure 8.--Wastewater collection, treatment facilities, and return flow points in Cumberland, Rhode Island. (Sources of data are listed in table 1.)

Two main interceptors serve the parts of Cumberland that have wastewater-collection systems, the Abbott Run Interceptor and the Blackstone Valley Interceptor (fig. 8). The Abbott Run Interceptor serves the eastern part of Cumberland and intersects the Blackstone Valley Interceptor near Cumberland's southern border with the neighboring town of Central Falls (BVI3). The Blackstone Valley Interceptor, which roughly parallels the Blackstone River valley, starts in the Cumberland Hill section of Cumberland, crosses the Blackstone River at the first measurement point at BVI8 to Lincoln and crosses back into Cumberland at BVI7. It is then joined in Cumberland by the Washington Highway Interceptor that serves Lincoln (BVI9). The Blackstone Valley Interceptor crosses into Lincoln at BVI6 and returns to Cumberland about one-third mile to the south BVI5. The final measurement point (BVI4) is at the Cumberland and Central Falls border.

The formula for calculating total wastewater collection from Cumberland is

$$\text{Wastewater collection} = BVI4 + BVI3 - BVI5 + BVI6 - BVI7 + BVI8 - BVI9.$$

Total wastewater collection from Cumberland during 1988 was 1.73 Mgal/d. Wastewater from Cumberland flows out of the study area to the Bucklin Point Wastewater Treatment Facility in East Providence and the treated wastewater is discharged into the Seekonk River (lower reach of the Blackstone River). For this study, the total of 1.73 Mgal/d was assigned to the BVI4 measurement point.

Blackstone VDC maintains a computer data base of customers and can aggregate data about their customers by location and size. The meters of the large users are read quarterly, and those of the **medium-sized users** are read annually. Water use by small users is estimated on the basis of the number of household units per meter. Large domestic, industrial, and commercial users in Cumberland who **release** water to Blackstone VDC are listed in appendixes 4, 5, and 6, respectively. Listings of the medium-sized and small users were also reviewed. Estimates of the volume of wastewater collected were developed by a review of the quarterly meter readings of each use category and comparison of the readings to estimates of the volume delivered by public-suppliers (table 4). The volume of water released by industrial users was estimated first because this group included the largest individual users. The large industrial users released 0.24 Mgal/d, large commercial users released 0.06 Mgal/d, and large domestic users released 0.03 Mgal/d (table 9).

Total industrial releases in Cumberland were 0.65 Mgal/d, of which 0.39 Mgal/d (table 7) was estimated as received by Blackstone VDC. Large industrial users released 0.24 Mgal/d into the Blackstone VDC wastewater-collection system during 1988 (appendix 5) and accounted for almost two-thirds of the water released by industries into the Blackstone VDC. The percentage of metered industrial releases is high because the water quality of industrial releases is monitored closely by Blackstone VDC.

Total commercial releases in Cumberland amounted to 0.25 Mgal/d, of which 0.11 Mgal/d (table 7) was estimated as received by Blackstone VDC. Large commercial users released 0.06 Mgal/d into the Blackstone VDC wastewater-collection system during 1988 (appendix 6), constituting about one-half of the water released by commercial users into the Blackstone VDC.

Table 9.--Wastewater collection by Blackstone Valley District Commission in Cumberland, 1988

[Data from the Blackstone Valley District Commission. Wastewater collection: M, metered; E, estimated; VDC, Valley District Commission; --, no data or not applicable]

	Wastewater collection, in million gallons per day									
		Domestic		Industrial		Commercial				
Utility	Total	Large	Small	Large	Small	Large	Small	Unaccounted for	Estimated population served	Per capita release, gallons per day
Blackstone VDC	1.73 M	0.03 M	0.88 E	0.24 M	0.15 E	0.06 M	0.05 E	0.32 E	12,530	73
Percentage of total wastewater collected	100	2	51	14	9	3	3	18	--	--

Total domestic releases in Cumberland amounted to 2.13 Mgal/d, of which 0.91 Mgal/d was estimated as received by Blackstone VDC. Large domestic users released 0.03 Mgal/d into the Blackstone VDC wastewater-collection system during 1988 (appendix 4). These users represented only 3 percent of water released by domestic users into the Blackstone VDC.

Releases by industrial, commercial, and domestic users constituted 82 percent of the volume metered by Blackstone VDC. The remaining 18 percent, 0.32 Mgal/d, was unmetered. Some of the unmetered water distributed by public suppliers may have ended up in the wastewater-collection system, especially where the user meters underregistered the volume of water delivered to the user. Most of the 0.32 Mgal/d, however, probably entered the wastewater-collection system either as runoff after storms through unsealed manhole covers, cross connections with storm drains, or basement sump pumps; or as **infiltration** from ground water through breaches in the wastewater pipes.

Wastewater Treatment

The second process in disposal, wastewater treatment, involves not only the removal of most of the solid constituents but also the chemical and biological treatment of wastewater. Wastewater treatment is intended to generate return flows that meet regulations designed to minimize the environmental effect at the point of release and on the hydrologic system. Wastewater collected in Cumberland is treated outside of the town of Cumberland. No public wastewater-treatment facilities are in Cumberland; however, four industries--Pacific Anchor Chemical Corp., Peterson Puritan, Inc., Pontiac Weaving Corp., and Standard Nut and Bolt Company (table 10)--treat their wastewater before releasing it into the Blackstone VDC collection system. This pre-treatment program is monitored by the Blackstone VDC. Another industry, The Okonite Company, treats its wastewater before discharging it into the Blackstone River. Electroformax Laboratories, Inc. and Pacific Anchor Chemical Corp. do not treat the water they release because it is noncontact cooling water.

Most consumptive use during disposal occurs during wastewater treatment; however, no data were available to make an estimate of this volume. As with distribution, substantial quantities of water may leak out of the system (**exfiltration**) during the wastewater-collection process. This can be considered a return flow. Water may also leak into the wastewater-collection system (infiltration) from runoff or from ground water if the water table is higher than the wastewater-collection pipes. Therefore, wastewater released into a collection system may be augmented by infiltration or depleted by exfiltration. Infiltration may be responsible for some of the 0.32 Mgal/d of unmetered surplus (table 7).

Self-Disposal Return Flow

Self-disposal is the return of wastewater directly to the hydrologic system after use. Return flow, the third process in disposal, occurs when water is returned to fresh surface water or ground water for reuse. Return flow can be discharged directly to surface water and ground water, particularly from a municipal or industrial wastewater-treatment facility, or indirectly to ground water through a septic system. Discharges to ground water in Cumberland can also occur by leakage from distribution and wastewater-collection lines.

Industrial return flow is composed of surface-water, septic-system, and direct ground-water return flow. Electroformax Laboratories, Inc., The Okonite Company, Pacific Anchor Chemical Corp. and Pawtucket WSB accounted for most of the surface-water return flow in Cumberland. These flows are monitored through the RIPDES program (table 10), which requires estimates for the average return flow to the Blackstone River, ground water, and septic systems; releases to Blackstone VDC; and evaporation from the facilities. The return flows are reported at least annually to the RI Department of Environmental Management; however, the reported return flows did not indicate the volume of each of the three types of return flow in 1988. Instead, the percentage of each type of release, as described in the industry's permit, was used to estimate the 1988 return flow to each destination.

The estimated discharge of water by Electroformax Laboratories, Inc., Pacific Anchor Chemical Corp. and The Okonite Company into the Blackstone River was 0.233 Mgal/d during 1988 (table 10). Industrial septic-system discharges were estimated at 0.02 Mgal/d, and industrial direct ground-water return flow was estimated at 0.01 Mgal/d (table 7).

Table 10.--Estimated water disposed by Rhode Island Pollutant Discharge Elimination System Permit holders in Cumberland, 1988

[Data from the Rhode Island Department of Environmental Management. Volume received is available to 0.001 Mgal/d because they are meter readings, not estimates. The numbers are reported here to indicate that the larger users category includes many more users than the major users category. Most of these meter readings would be either .01 or <.01 if rounded to 0.01 as in the text; Blackstone GWR, Blackstone River ground-water reservoir; BVDC, Blackstone Valley District Commission; CWD, Cumberland Water Department; EVAP, Evaporation; --, not applicable; PWSB, Pawtucket Water Supply Board; RIPDES, Rhode Island Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Septic, Septic System; WWC, Wastewater Collection System]

Name and address	RIPDES number	SIC code	Source of water	Return flow, million gallons per day					
				Blackstone River	Abbott Run	Blackstone GWR	Septic	WWC BVDC	Consumptive use EVAP
Electroformax Laboratories, Inc. 1 Front Street	RI0021504	3079	CWD & wells	0.018	--	--	0.001	--	0.002
The Okonite Company 111 Martin Street	RI0020141	3357	CWD	.117	--	0.001	--	--	.002
Pacific Anchor Chemical Corp. 1224 Mendon Road	RI0020451	2841	CWD	.098	--	.003	--	0.008	.001
Pawtucket Water Supply Board 120 Mill Street	RI0001589	4941	PWSB	--	0.192	--	--	--	--
Totals				.233	.192	.004	.001	.008	.005

The largest volume of return flow in Cumberland is from domestic septic systems. Approximately 55.8 percent of Cumberland households are on septic systems; the remaining 44.2 percent are served by the Blackstone VDC. Domestic return flow through septic systems was estimated at 1.22 Mgal/d, and commercial return flow through septic systems was estimated at 0.14 Mgal/d (table 7). Direct ground-water return flow was estimated as including approximately 41 percent of the unmetered use in Cumberland, 0.22 Mgal/d, primarily in the form of leaks from public supply lines and wastewater collection lines in areas where the water table is low.

Half of the septic systems were estimated to be in the Blackstone subbasin and half in the Abbott Run subbasin. Assuming that no septic systems were in the bedrock, ground-water return flow through septic systems was divided among till (about 87 percent), the Blackstone Valley ground-water reservoir (about 2 percent), and Abbott Run ground-water reservoir (about 11 percent), which is roughly equivalent to their areal extent and population densities. Commercial septic-system return flow and unmetered use direct ground-water return flow was estimated by the same method.

Other self-disposed water in Cumberland includes discharge of filter backwash and livestock use. Surface-water return flow from water treatment was estimated at 0.19 Mgal/d into Abbott Run by Pawtucket WSB and less than 0.01 Mgal/d into Sneech Pond by Cumberland WD. Direct ground-water return flow after livestock use was less than 0.01 Mgal/d (table 7).

Overview

Disposal water-use data (wastewater collection, wastewater treatment, and return flow) describe the removal of wastewater from the point of use. The disposal overview concentrates on how much water in Cumberland is unavailable for use because of exportation for wastewater treatment and consumptive use, how the disposal of water differs by category of use, and which resources are affected by the return flow. Summary data on disposal in Cumberland are listed in table 11 and displayed graphically in figure 9. Cumberland does not receive any imported water for return flow; however, 46 percent of all water released after use (1.73 Mgal/d) was exported from Cumberland for treatment (fig. 9*A*) and subsequent return flow by Blackstone VDC.

An estimated 2.03 Mgal/d was released as return flow in Cumberland during 1988. Return flow after domestic use (1.22 Mgal/d) constituted 60 percent of all return flow in Cumberland (fig. 9*B*). Industrial return flow (0.26 Mgal/d) constituted 13 percent, public-supply return flow from backwashing filters during water treatment (0.19 Mgal/d) constituted 9 percent, and commercial return flow (0.14 Mgal/d) constituted 7 percent. Approximately 11 percent of return flow was through leakage. Return flow after livestock and irrigation use was less than 0.01 Mgal/d.

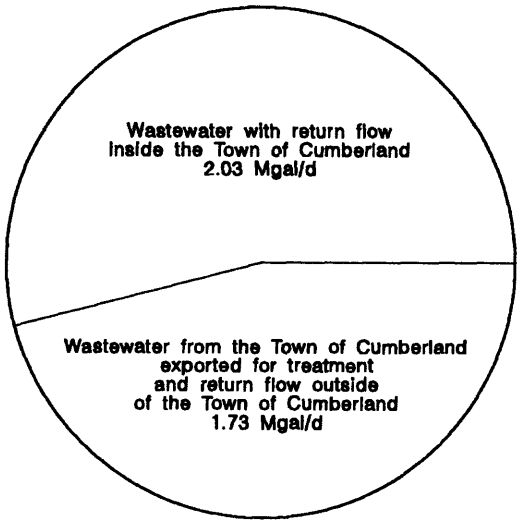
Return flow within the Blackstone River subbasin (0.91 Mgal/d) constituted 45 percent of return flow in Cumberland (fig. 9*C*). This return flow is about 54 percent of the water withdrawn in the Blackstone River subbasin (fig. 5*A*). Return flows in the Abbott Run subbasin total 1.12 Mgal/d. This return flow is about 8 percent of the water withdrawn in the Abbott Run subbasin. Approximately 11 percent (0.23 Mgal/d) of return flow in Cumberland was to surface water in the Blackstone River subbasin, and approximately 9 percent (0.19 Mgal/d) was to surface water in the Abbott Run subbasin.

Ground-water return flow (1.61 Mgal/d), a combination of septic-system (1.38 Mgal/d; table 7) and direct ground-water return flow (0.23 Mgal/d), constituted 79 percent of all return flow in Cumberland. Ground-water return flow was about 82 percent of ground-water withdrawal. Return flow to till (1.40 Mgal/d) accounted for 87 percent of ground-water return flow in Cumberland (fig. 9*D*) primarily because of the large percentage of the population with septic systems. Return flow to Abbott Run (0.17 Mgal/d) and Blackstone (0.04 Mgal/d) ground-water reservoirs accounted for 11 and 2 percent, respectively. Consumptive use during disposal was less than 0.01 Mgal/d.

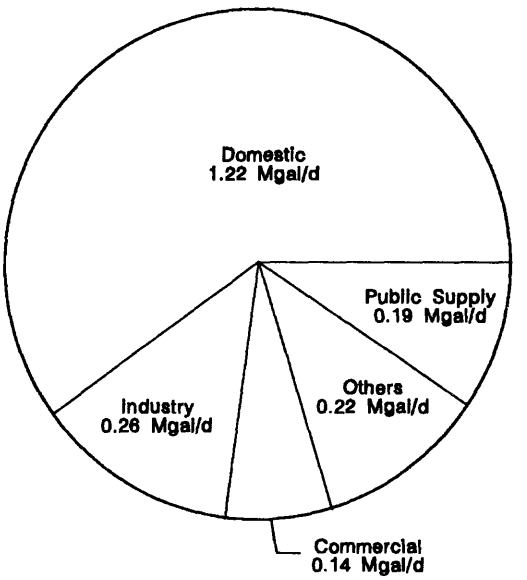
Table 11.--Return-flow summary for Cumberland, 1988

[Data from the Rhode Island Department of Environmental Management, Cumberland Water Department, Pawtucket Water Supply Board, and Blackstone Valley District Commission. GWR, ground-water reservoir. Return flow in million gallons per day; <, less than; --, no data or not applicable. Columns may not add to totals because of independent rounding]

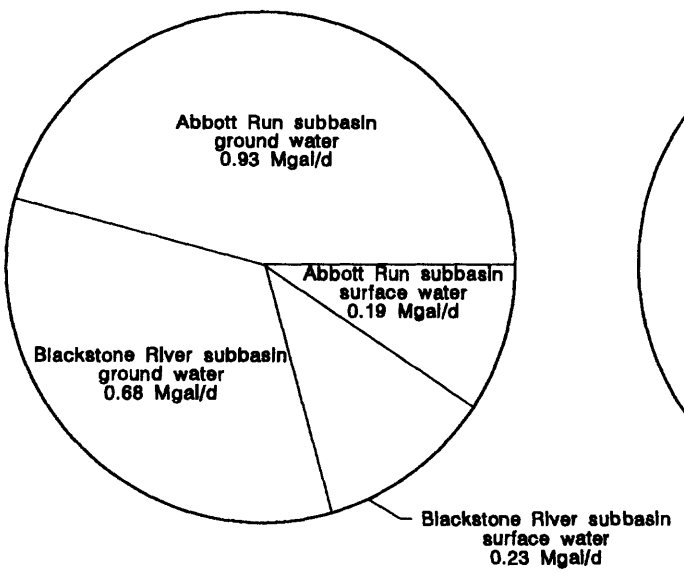
	Public supply	Domestic	Indus-trial	Commer-cial	Other	Ground-water total	Surface-water total	Subbasin total
BLACKSTONE RIVER SUBBASIN								
Surface water	<0.01	--	0.23	--	--	--	0.23	
Ground water								
Blackstone GWR	--	0.03	.01	<0.01	<0.01	0.04	--	
Till aquifer	--	.48	<.01	.07	.09	.64	--	
Blackstone totals	<.01	.51	.24	.07	.09	.68	.23	0.91
ABBOTT RUN SUBBASIN								
Surface water	.19	--	--	--	--	--	0.19	
Ground water								
Abbott Run GWR	--	.13	.01	.01	.02	.17	--	
Till aquifer	--	.58	.01	.06	.11	.76	--	
Abbott Run totals	.19	.71	.02	.07	.13	.93	.19	1.12
Cumberland totals	.19	1.22	.26	.14	.22	1.61	.42	2.03
Total exported from Cumberland								1.73



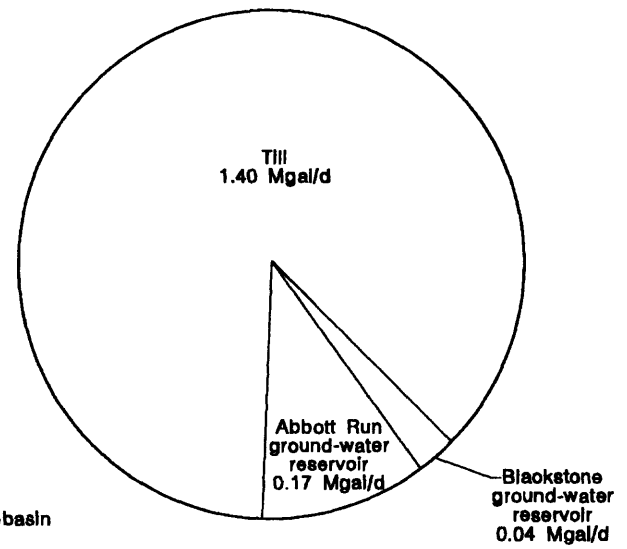
A. LOCATION OF RETURN FLOW



B. USE CATEGORY



C. BASIN



D. AQUIFER

EXPLANATION

Mgal/d Millions gallons per day

Figure 9.--Return flow of wastewater by (*A*) location of return flow, (*B*) use category, (*C*) basin, and (*D*) aquifer in Cumberland, Rhode Island. (Sources of data are listed in table 1.)

SUMMARY AND CONCLUSIONS

The complex decisions required in water-resource management depend on the availability of accurate and comprehensive data on all six water-use processes: (1) withdrawal, (2) water use, (3) return flow, (4) consumptive use, (5) treatment, and (6) conveyance. Each of the processes needs to be evaluated if one is to determine how water use has changed the availability and distribution of water resources. Water-use data collected in Rhode Island by different State agencies or maintained by different public suppliers and wastewater-treatment facilities need to be integrated for use in making water-resource management decisions. Careful planning of water-use-data collection, analysis of whether collected data meet water-resource management needs, coordination between State agencies, and a computerized data-management system would be required to track the flow of water through Rhode Island's complex water systems. Water-use data for the town of Cumberland, a small area in northeastern Rhode Island, were acquired and integrated to provide an example of how available data could be integrated throughout the rest of the State.

The current lack of standard methods for collecting and storing water-use data in Rhode Island made water-use data compilation and analysis difficult. Data standardization could be facilitated by the adoption of consistent definitions of user categories that are based on the Standard Industrial Classification (SIC) Codes, use of the complete address for users, development of a method to simultaneously update metering and billing account names at the public suppliers and wastewater-treatment facilities, notation of whether supply or disposal is public or private, and records of the volume of water at critical points during use. Critical use points include withdrawal, after water treatment, at the point of delivery for use, after use by high-volume users, at major wastewater-collection points, at the point of entry into wastewater-treatment facilities, and at return to the resource. Accuracy of data on deliveries to customers could be improved if the reported meter readings were verified by use of a computerized editing program to detect anomalies. Reliability of data could be improved by documentation of the type and method of measurement and accuracy of the reported volume of water use.

Supply and disposal data in Cumberland illustrate the net effect of water use on the availability and distribution of water resources. Water-use patterns provide information that can assist in the development of management plans that maximize the efficient use of current resources.

Supply data (withdrawal, water treatment, and distribution) indicate which resources are affected by withdrawal, how water is used, and how much water in Cumberland becomes unavailable for use because of exportation and consumptive use. The total volume of water withdrawn in Cumberland in 1988 was estimated at 15.39 Mgal/d, of which 13.42 Mgal/d was from surface water and 1.97 Mgal/d was from ground water. Withdrawal for public supply (15.11 Mgal/d) accounted for 98 percent of all withdrawal. Seventy-three percent of the withdrawal (11.20 Mgal/d) was exported for supply to other towns.

Water use, in the restrictive sense, refers to total water received by users, consumptive use, and total water released by users. Total water received for use during 1988 included 2.51 Mgal/d (table 7) for domestic use (93 percent from public supply), 0.68 Mgal/d for industrial use (88 percent from public supply), 0.27 Mgal/d for commercial use (93 percent from public supply), and 0.73 Mgal/d for other uses; a total of 4.19 Mgal/d. Consumptive use in 1988 was estimated at

0.43 Mgal/d. Total water released after use included 2.13 Mgal/d after domestic use (43 percent into public disposal), 0.65 Mgal/d after industrial use (60 percent into public disposal), 0.25 Mgal/d after commercial use (44 percent into public disposal), and 0.73 Mgal/d for other uses.

Disposal data (wastewater collection, wastewater treatment, and return flow) indicate which surface-water and ground-water resources are affected by return flow, how the users dispose of water after use, and how much water in the town becomes unavailable for use because of exportation for wastewater treatment and consumptive use. During 1988, the total volume of water returned to the hydrologic system in Cumberland was 2.03 Mgal/d, which included 1.38 Mgal/d returned to ground water through septic systems, 0.23 Mgal/d returned directly to ground water, and 0.42 Mgal/d returned to surface water. Return flow after domestic use was 1.22 Mgal/d (60 percent of return flow), after industrial use was 0.26 Mgal/d (13 percent), after water treatment was 0.19 Mgal/d (9 percent), and after commercial use was 0.14 Mgal/d (7 percent). Approximately 0.22 Mgal/d (11 percent of return flow) was through leakage. About 1.73 Mgal/d was exported from Cumberland for wastewater treatment.

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GLOSSARY

The following are definitions of selected technical terms as they are used in this report; they are not necessarily the only valid definitions for these terms. Terms defined in the glossary are in bold print where first used in the main body of this report.

Clearwell.--A reservoir for the storage of filtered water of sufficient capacity to prevent the need to vary the filtration rate with variations in demand. Also used to provide chlorine-contact time for disinfection.

Conveyance.--The systematic and intentional movement or transfer of water from one point to another. Three conveyance types are relocation, distribution, and wastewater collection.

Consumptive use.--Water that evaporates or transpires from irrigated plants; is transpired by humans or domestic animals; is incorporated into products, domestic animals, or crops; evaporates from open storage, treatment, or conveyance systems; or discharges into brackish or saline waters after use (assuming that it was withdrawn as freshwater).

Delivery.--Water received by a user or group of users through a public supply distribution system.

Disposal.--All of the processes that are involved with removing wastewater from the point of use. Includes wastewater collection, wastewater treatment, and return flow.

Distribution conveyance.--The process of conveying water from a public supplier's points of withdrawal or treatment through the distribution system to the users. Water is released from the public supplier into the distribution system and delivered to users. Distributed water will be equal to total deliveries plus unaccounted-for water. Water can also be delivered to another public supplier for distribution.

Exfiltration.--Water that leaks from a conveyance system or storage area into the surrounding and underlying materials. This process will occur if the ambient ground-water pressure is less than the internal pressure of the conveyance system or storage area at a point of breach (leakage).

Infiltration.--Water that infiltrates into a low-pressure or unpressurized conveyance system, such as a wastewater-collection system. This process will occur if the ambient ground-water pressure exceeds the internal pressure of the conveyance system at a point of breach (leakage).

Large user.--A user requiring a significant volume of water as defined by a utility, frequently on the basis of criteria that are specific to the utility and that may reflect past, current, or anticipated volumes delivered to or released by the user. The distinction between large and small users is made by the utility and is not the same as major and minor users as defined in this report. Meters of large users are read monthly or quarterly.

Major user.--A user who withdraws, distributes, or uses water, or collects or returns wastewater an average of more than 10,000 gal/d (0.01 Mgal/d).

Medium user.--A user group, sometimes identified by a utility on the basis of criteria that are specific to the utility and that may reflect past, current, or anticipated volumes delivered to or released by the user, whose water meter is read not as frequently as a large user but more frequently than a small user.

Minor user.--A user who withdraws, distributes, or uses water, or collects or returns wastewater an average of less than 10,000 gal/d (0.01 Mgal/d).

Release.--Water discharged by a user or group of users into a wastewater-collection system.

Return flow.--Water that is returned to fresh surface water or ground water and thus 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 septic systems.

Small user.--A user, defined by a utility frequently on the basis of criteria that are specific to the utility and that may reflect past, current, or anticipated volumes delivered to or released by the user. The distinction between large and small users is made by the utility and is not the same as major and minor users. Meters of small users are read quarterly or annually, or are estimated.

Supply.--All of the processes that are involved in supplying the user with water. Includes withdrawal, water treatment, and distribution conveyance.

Total water received.--The sum of all water delivered to or withdrawn by a user or group of users within an area.

Total water released.--The sum of all water released after use by a user or group of users within an area to an onsite wastewater-treatment facility, to a collection system for offsite wastewater treatment, or as return flow.

Treatment.--Processes that alter the physical or chemical characteristics of water.

Wastewater-collection conveyance.--The process of conveying wastewater, which also may include storm runoff, through a wastewater-collection system (sewer system) to a wastewater-treatment facility. Wastewater is released by the user into the collection system and received by the treatment facility. Wastewater also can be released from a local collection system into a regional collection system.

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

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

Water treatment.--The processes that withdrawn water may undergo before use, including chlorinization, fluoridation, and filtration.

Water use.--1. In a restrictive sense, water that is actually used for a specific purpose or purposes, such as for domestic purposes, irrigation, or industrial processing. 2. More broadly, human interaction with and influence on the hydrologic cycle, including elements such as water withdrawal, distribution, consumptive use, wastewater collection, and return flow.

Wellhead.--The above-ground part of a well.

Withdrawal.--The removal of surface water or ground water from the natural hydrologic system for use.

APPENDIX 1.--Large domestic users who received water from public suppliers in Cumberland, 1988

[Data from Cumberland Water Department and Pawtucket Water Supply Board. Volume received is available to 0.001 Mgal/d because they are meter readings, not estimates. The numbers are reported here to indicate that the larger users category includes many more users than the major users category. Most of these meter readings would be either .01 or <.01 if rounded to 0.01 as in the text; Blackstone VDC, Blackstone Valley District Commission; SIC code, standard industrial classification code; *, major user (more than 0.01 million gallons per day)]

Name and address	Miscellaneous use data	SIC code	Water received, in million gallons per day	Type of disposition
USERS SUPPLIED BY CUMBERLAND WATER DEPARTMENT				
Bear Hill Village Apts Bear Hill Road	126 units	8811	0.008	Blackstone VDC
Chimney Hill Development 2065 Mendon Road	Apartment building	8811	.003	Septic system
Diamond Hill Nursing 3579 Diamond Hill Road	50 employees	8051	.005	Septic system
*Maplewood Condominiums 2970 Mendon Road	97 units	8811	.014	Blackstone VDC
Arlington Villa	7 units	8811	.001	Blackstone VDC
Belmont Villa	10 units	8811	.001	Blackstone VDC
Cambridge Villa	10 units	8811	.001	Blackstone VDC
Dartmouth Villa	6 units	8811	.002	Blackstone VDC
Exeter Villa	10 units	8811	.002	Blackstone VDC
Jamestown Villa	10 units	8811	.001	Blackstone VDC
Lexington Villa	10 units	8811	.001	Blackstone VDC
Newport Villa	9 units	8811	.001	Blackstone VDC
Plymouth Villa	10 units	8811	.001	Blackstone VDC
Barrington Villa	9 units	8811	.002	Blackstone VDC
Chestnut Villa	6 units	8811	.001	Blackstone VDC
Mt St. Rita's Novitiate Wrentham Road		8811	.002	Septic system
Riverside Village 1 Flat Street	88 units	8811	.005	Septic system
Rustic Village Assoc 99 Manville Hill Road	24 units	8811	.003	Blackstone VDC
Total			.040	
USERS SUPPLIED BY LIPPITT ESTATES COMMUNITY ASSOCIATION				
*Lippitt Estates Community Association Lippitt Avenue	280 people	8811	0.018	Septic system
USERS SUPPLIED BY PAWTUCKET WATER SUPPLY BOARD				
Cumberland Housing Auth Mendon Road & Mill St.		8811	0.009	Blackstone VDC
Grandview Nursing Home Chambers Street	100 employees	8051	.006	Blackstone VDC
Total			.015	

APPENDIX 2.--Large industrial users who received water from public suppliers in Cumberland, 1988

[Data from Cumberland Water Department and Pawtucket Water Supply Board. Water received is available to 0.0001 Mgal/d because they are meter readings, not estimates. The numbers are reported here to indicate that the larger users category includes many more users than the major users category. Most of these meter readings would be either .01 or <.01 if rounded to 0.01 as in the text; Blackstone VDC, Blackstone Valley District Commission; RIPDES, Rhode Island Pollutant Discharge Elimination System; SIC code, standard industrial classification code; --, unknown; *, major user (more than 0.01 million gallons per day; #, pretreats water before release into the wastewater-collection system]

Name and address	SIC code	Water received, in million gallons per day	Type of disposition
USERS SUPPLIED BY CUMBERLAND WATER DEPARTMENT			
Crystal Thermoplastics Industrial Road	3089	0.001	Blackstone VDC
Health Tex 88 Martin 2 Industrial Road	2369 --	.008	Blackstone VDC
Herrick & White Ltd. 3 Flat (Manville Hill)	2431	.003	Blackstone VDC
*Lonza, Inc. 1224 Mendon Road	2841	.111	Blackstone VDC#
Lynch, J.H., & Sons First Street	1611	.001	Septic system
Mossberg Pressed Steel 160 Bear Hill Road	3469	.002	Septic system
North Penn Transfer Inc. Industrial Road	--	.003	Blackstone VDC
*The Okonite Company 111 Martin Street	3357	.120	RIPDES
O'Toole, Mary Alice Martin Street	--	.001	Blackstone VDC
*Peterson Puritan, Inc. Martin Street	2213	.124	Blackstone VDC#
Ronald Pratt 10 Industrial Road	3915	.001	Blackstone VDC#
Superior Healthcare Group Industrial Park	3842	.006	Blackstone VDC
Taft Pierce Industrial Road	3545	.001	Blackstone VDC
Teknor Apex Company Industrial Road	--	.008	Blackstone VDC
Tech Machining Services 1 Angell Road	3599	.003	Septic system
Total		.393	

APPENDIX 2.--Large industrial users who received water from public suppliers in Cumberland, 1988--Continued

Name and address	SIC code	Water received, in million gallons per day	Type of disposition
USERS SUPPLIED BY PAWTUCKET WATER SUPPLY BOARD			
American Steel & Aluminum 293 Dexter Street	--	.0003	Septic system
Cadillac Mills Meeting Street	--	.001	Blackstone VDC
Comtec Information System 53 John Street	3695	.001	Blackstone VDC
Hindley Manufacturing 9 Havens Street	3452	.005	Blackstone VDC
Magco Plastics 4 Mill Street	3915	.003	Blackstone VDC
*Pontiac Weaving Corp. Meeting Street	2241	.017	Blackstone VDC#
*Standard Nut and Bolt Co. 49 Abbott Street	3452	.022	Blackstone VDC
Total		.049	

APPENDIX 3.--Large commercial users who received water from public suppliers in Cumberland, 1988

[Data from Cumberland Water Department and Pawtucket Water Supply Board. Water received is available to 0.001 Mgal/d because they are meter readings, not estimates. The numbers are reported here to indicate that the larger users category includes many more users than the major users category. Most of these meter readings would be either .01 or <.01 if rounded to 0.01 as in the text; Blackstone VDC, Blackstone Valley District Commission; SIC code, standard industrial classification code; *, major user (more than 0.01 million gallons per day]

Name and address	SIC code	Water received, in million gallons per day	Type of disposition
USERS SUPPLIED BY CUMBERLAND WATER DEPARTMENT			
Abbott Run Valley Swim Club Sneech Pond Road	7991	0.005	Septic system
Cumberland High School 2660 Mendon Road	8211	.002	Blackstone VDC
Cumberland School Scott Road	8211	.001	Septic system
Fore Court Tennis Club 44 Cray Street	7991	.009	Blackstone VDC
KPS Laundry High & Holly Street	7211	.005	Blackstone VDC
Mt. St. Rita's Health Club Highland View Road	7991	.007	Septic system
North Cumberland Middle School Nate Whipple Highway	8211	.002	Septic system
Roger Williams Grocery 1 IGA Way	5141	.007	Blackstone VDC
Tonetti Carwash 1676 (1700) Mendon Road	7542	.008	Blackstone VDC
Valley Gas Company 1595 Mendon Road	4922	.002	Septic system
Total		.048	

APPENDIX 3.--Large commercial users who received water from public suppliers in Cumberland, 1988--Continued

Name and address	SIC code	Water received, in million gallons per day	Type of disposition
USERS SUPPLIED BY THE PAWTUCKET WATER SUPPLY BOARD			
*Ann and Hope Factory Outlet 47 Cross Street	5311	.019	Septic system
Clydes Food & Spirits 403 Mendon Road	5812	.002	Septic system
Cumberland School Administration Highland Avenue	8211	.001	Blackstone VDC
Dias, Jorge 180 Broad Street	unknown	.004	Blackstone VDC
Kitsilis, Angelo 131 Mendon Road	unknown	.001	Blackstone VDC
*Mackland Realty, Inc. 52-60 Mendon Road	unknown	.012	Blackstone VDC
McDonalds Corp. 100 Mendon Road	5812	.002	Blackstone VDC
Pub Dennis 356 Mendon Road	5813	.004	Septic system
St. Patrick's Church School 259 Broad Street	8211	.001	Blackstone VDC
Terra Almacs R. 75 Mendon Road	unknown	.001	Blackstone VDC
Valley Falls Fire District 555 High Street	9221	.003	Blackstone VDC
Total		.050	

APPENDIX 4.--Large domestic users who released water to the Blackstone Valley wastewater-collection system in Cumberland, 1988.

[Data from the Blackstone Valley District Commission. Wastewater released is available to 0.001 Mgal/d because they are meter readings, not estimates. The numbers are reported here to indicate that the larger users category includes many more users than the major users category. Most of these meter readings would be either .01 or <.01 if rounded to 0.01 as in the text; SIC code, standard industrial classification code; *, major user (more than 0.01 million gallons per day); CWD, Cumberland Water Department; PWSB, Pawtucket Water Supply Board; --, meter reading not collected quarterly, volume not requested of Blackstone Valley District Commission]

Name and address	Miscellaneous use data	SIC code	Source	Wastewater released in million gallons per day
Bear Hill Village Apts Bear Hill Road	126 units	8811	CWD	0.008
Cumberland Housing Auth Mendon Road & Mill St.		8811	PWSB	.009
Grandview Nursing Home Chambers Street		8051	PWSB	.006
*Maplewood Condominiums 2970 Mendon Road	97 accounts	8811	CWD	.012
Rustic Village Assoc 99 Manville Hill Road	24 units	8811	CWD	--
Total				.035

APPENDIX 5.--Large industrial users who released water to the Blackstone Valley wastewater-collection system in Cumberland, 1988

[Data from the Blackstone Valley District Commission. Wastewater released is available to 0.001 Mgal/d because they are meter readings, not estimates. The numbers are reported here to indicate that the larger users category includes many more users than the major users category. Most of these meter readings would be either .01 or <.01 if rounded to 0.01 as in the text; SIC code, standard industrial classification code; *, major user (more than 0.01 million gallons per day); CWD, Cumberland Water Department; PWSB, Pawtucket Water Supply Board; #, pretreats water before release into the wastewater-collection system; --, meter reading not collected quarterly, volume not requested of Blackstone Valley District Commission]

Name and address	SIC code	Source	Wastewater released in million gallons per day
Cadillac Mills Meeting Street	unknown	PWSB	0.001
Comtec Information System 53 John Street	3695	PWSB	--
Crystal Thermoplastics Industrial Road	3089	CWD	--
Health Tex	2369	CWD	
88 Martin			.002
2 Industrial Road			.005
Herrick & White Ltd. 3 Flat (Manville Hill)	2431	CWD	--
Hindley Manufacturing 9 Havens Street	3452	CWD	.005
Magco Plastics 4 Mill Street	3915	PWSB	.034
O'Toole, Mary Alice Martin Street	unknown	CWD	--
*Pacific Anchor Chemical Corp. (Lonza) 1224 Mendon Road	2841	CWD	.008#
*Peterson Puritan, Inc. Martin Street	2213	CWD wells	.128#
*Pontiac Weaving Corp. Meeting Street	2241	PWSB	.025#
Ronald Pratt 10 Industrial Road	3915	CWD	.001
*Standard Nut and Bolt Co. 49 Abbott Street	3452	PWSB	.022#
Superior Healthcare Grp Industrial Park	3842	CWD	.006
Taft Pierce Industrial Road	3545	CWD	--
Teknor Apex Company Industrial Road	unknown	CWD	.003
Total			.240

APPENDIX 6.--Large commercial users who released water to the Blackstone Valley wastewater-collection system in Cumberland, 1988.

[Data from the Blackstone Valley District Commission. Wastewater released is available to 0.001 Mgal/d because they are meter readings, not estimates. The numbers are reported here to indicate that the larger users category includes many more users than the major users category. Most of these meter readings would be either .01 or <.01 if rounded to 0.01 as in the text; SIC code, standard industrial classification code; *, major user (more than 0.01 million gallons per day); CWD, Cumberland Water Department; PWSB, Pawtucket Water Supply Board; --, meter reading not collected quarterly, volume not requested of Blackstone Valley District Commission; ?, source undocumented]

Name and address	SIC code	Source	Wastewater released in gallons gallons per day
Benoit & Bordes 3231 Mendon Road	unknown	CWD?	0.001
Clemente 447 Broad Street	unknown	PWSB	.002
Cumberland High School 2660 Mendon Road	8211	CWD	.002
Cumberland School Admin Highland Avenue	8299	PWSB	--
Dias, Jorge 180 Broad Street	unknown	PWSB	.004
Figueiredo, Jose 168 Broad Street	unknown	PWSB	.002
Fore Court Tennis Club 44 Cray Street	7941	CWD	.011
Gershman & Bannon 433 Broad Street	unknown	PWSB	.001
Goncalves & Santos 180 Broad Street	unknown	PWSB	.001
Kitsilis, Angelo 131 Mendon Road	unknown	PWSB	--
Kolor Quick, Inc. 1850 Mendon Road	7395	?	--
KPS Laundry High and Holly Streets	7211	CWD	.006
*Mackland Realty, Inc. 52-60 Mendon Road	unknown	PWSB	.015
McDonalds Corp. 100 Mendon Road	5812	PWSB	.002
Roger Williams Grocery 1 IGA Way	5141	CWD	.003
St. Patrick's Church Scl 259 Broad Street	8661	PWSB	--
Terra Almacs R 75 Mendon Road	unknown	PWSB	001
Tonetti Carwash 1676 (1700) Mendon Road	7542	CWD	.008
Valley Falls Fire District 447 Broad Street	unknown	PWSB	--
Total			.059

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