Water Resources of the Waterbury-Bristol Area Connecticut

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1499-J

Prepared in cooperation with the Connecticut Water Resources Commission and the New Britain Board of Water Commissioners

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By R. V. CUSHMAN, F. H. PAUSZEK, A. D. RANDALL *and* M. P. THOMAS

Revised by H. L. BALDWIN

WATER RESOURCES OF INDUSTRIAL AREAS

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WATER RESOURCES OF THE WATERBURY-BRISTOL AREA, CONNECTICUT

By R. V. Cushman, F. H. Pauszek, A. D. Randall, and M. P. Thomas

ABSTRACT

This report discusses the water resources in the area of Bristol, Plymouth, Waterbury, and Wolcott, Conn., towns which have a combined population of 170,000.

The area uses 78 mgd (million gallons per day) of water annually, most of which comes from the Naugatuck and Pequabuck Rivers and their tributaries; the rest is ground water. The surface-water supply is more than sufficient for further demands, but in many areas it is restricted for use because of pollution. The ground water is generally of acceptable quality, but is often available in amounts sufficient only for domestic use.

In the Waterbury area, the Naugatuck River and other surface-water sources supply 96 percent of the water. The riverflow averages 307 mgd a few miles below Waterbury. The quality varies with the amount of flow and industrial recharge; the temperature ranges from around freezing in the winter to 80° F. in the summer. Moderate supplies of water of good quality are available in the alluvium along the streams. The area used approximately 70 mgd in 1959, 82 percent in industry.

In the Bristol area, the Pequabuck River supplies most of the necessary water. The chemical quality of the river seems very good and the average flow in the area is 56.3 mgd. Small to moderate supplies are drawn from the sand and gravel deposits near the rivers and throughout the area. It is estimated that the area used 2.5 billion gallons in 1959.

In the rural area, small quantities of generally good quality water are available from the glacial deposits and bedrock. The total use of water (mostly domestic) in this area, in 1959, was 345 million gallons.

Included in the report are water analyses, flow records, and well records which give more detailed information for present and future development of the area's water resources.

ACKNOWLEDGMENTS

The authors acknowledge the courtesy and cooperation of Messrs. W. S. Wise, director, Connecticut Water Resources Commission; W. J. Scott, director, Bureau of Sanitary Engineering, Connecticut Department of Health; John Kelly, assistant superintendent, Waterbury Water Department; J. L. Bean, superintendent, Bristol Water

Department; Neal MacKenzie, president, Terryville Water Co.; G. W. Wood, chief engineer, New Britain Water Department; and W. H. Hoovel, assistant city engineer, Waterbury Bureau of Engineering.

Most of the data summarized in the report were collected over a period of many years by the U.S. Geological Survey in cooperation with the Connecticut Water Resources Commission and the New Britain Board of Water Commissioners. Additional information and records were furnished by the Bristol Water Department, Terryville Water Co., Waterbury Water Department, well drillers, and many officials of industrial concerns in the area.

PURPOSE AND SCOPE OF THIS REPORT

Wherever it occurs, water poses certain questions to its users. Where does it come from? How much is there at a given time? What is its chemical quality? Is it hard or soft? How can it be kept clean and pure, or made so again once it has been polluted? Are floods a danger to the community? How can the local water resources be managed to meet all the conflicting needs of people, industries, flood control and recreation?

This report outlines these questions as they relate to the Connecticut cities of Waterbury and Bristol, and the adjoining towns of Plymouth and Wolcott. The report summarizes and evaluates information on the water resources and water use of the Waterbury-Bristol area, as of 1959, and contains data useful to industries and municipalities for planning new waterworks or expanding existing facilities. It describes the quantity, quality, and physical characteristics of the surface and ground water at certain sites within the area.

The report cannot pretend to answer all the questions it presents, as each problem requires its own detailed investigation and design study. However, the industrial expansion and the normal growth of cities and suburban communities require adequate and continuing appraisals of water resources to assure sound management of present and potential supplies. This report is such an appraisal. We hope it will be useful both to those involved in water management and to others who are interested in water.

DESCRIPTION OF THE AREA

LOCATION

The Waterbury-Bristol area is in west-central Connecticut in the drainage basins of the Naugatuck and Pequabuck Rivers (fig. 1). As considered in this report, the area includes the city of Waterbury and the town of Wolcott in New Haven County, the city of Bristol

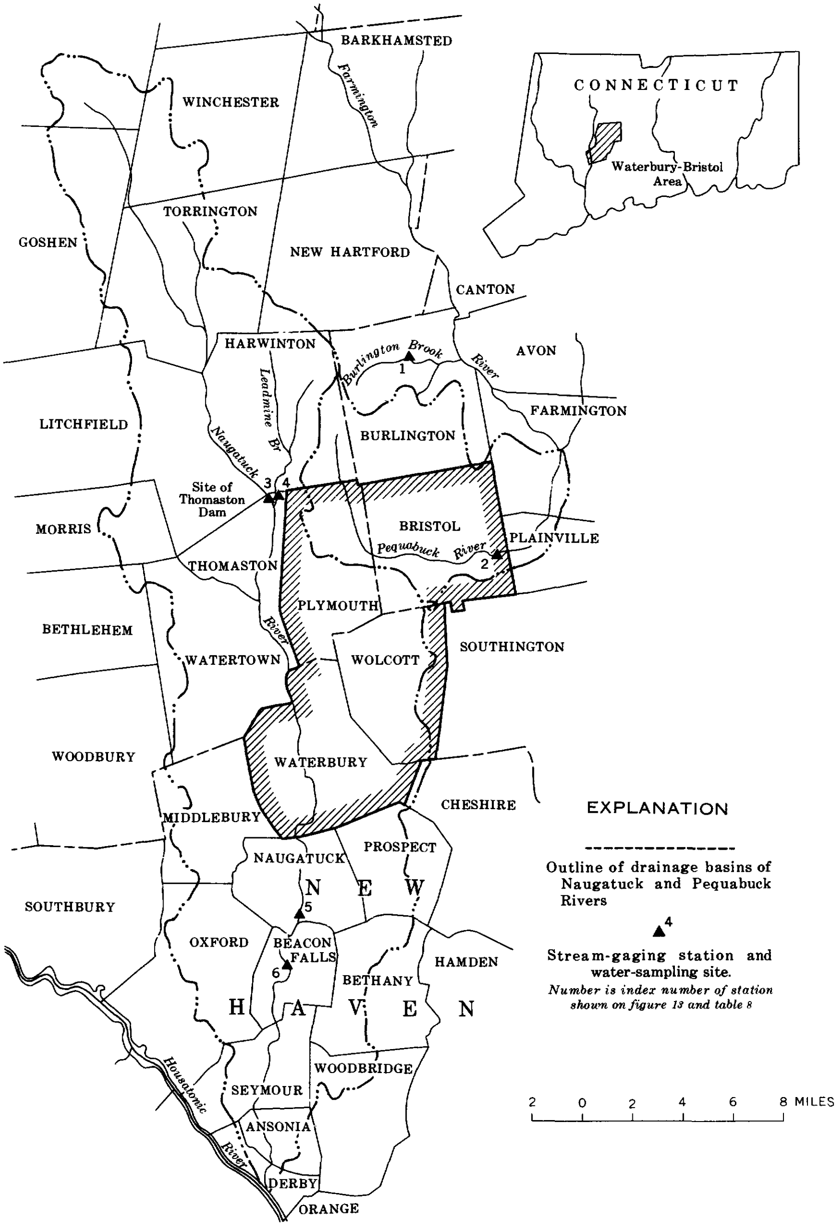


FIGURE 1.—Location and extent of the Waterbury-Bristol area, major drainage basins, stream-gaging stations, and water-sampling sites.

in Hartford County, and the town of Plymouth in Litchfield County. It includes the metropolitan areas of Waterbury and Bristol and the intervening rural area, encompassing 98.3 square miles in all. Generally, the country is rugged, consisting of hills and discontinuous ridges that have resulted from erosion. The valleys of the major streams cut deeply into this rolling terrain. The only level land is in the flood plains of the Naugatuck and Pequabuck Rivers and in scattered tracts in the hilly areas that are underlain by deposits of sand and gravel (pl. 1). Altitudes range from 200 feet above sea level near the Naugatuck and Pequabuck Rivers at Waterbury and Forestville, respectively, to about 1,000 feet at the summits of several of the discontinuous ridges. Except for a small strip on the east, the entire area is drained by the Naugatuck and Pequabuck Rivers (pl. 1).

To simplify the description of the water supply and to increase the utility of the report, the Waterbury-Bristol area has been divided into three subareas: Waterbury, Bristol, and Rural. The outlines of the subareas intentionally are not exactly defined and not shown on the regional maps. Generally, the Waterbury and Bristol subareas include the urban and suburban parts of Waterbury and of Bristol and Terryville. The Rural subarea includes the remainder of the four towns covered by the report.

DEVELOPMENT OF INDUSTRY

Waterbury was founded in 1644 as Mattatuck Plantation by settlers from Farmington, Conn. In 1686 the village was incorporated and changed its name to Waterbury. The land on which the present city of Bristol stands was bought from the Tunxis Indians and settled as Tunxis Plantation. The city of Bristol was incorporated in 1785.

Although the earliest settlers were farmers, the Waterbury-Bristol area soon became an important industrial center. As early as 1750, skilled artisans in Waterbury made brass buckles; later they made brass buttons, clocks, oil lamps, pins, and other brass products. The raw material was scrap taken from old copper pieces and fittings, ship sheathing, etc. It was hand-fused and rolled by homemade machinery which was driven by horsepower. In 1857 the Waterbury Clock Co. was established and undertook the manufacture of the Ingersoll watches. By the middle of the 19th century, Waterbury was firmly established as the leading center of brass manufacture in the United States. The city was incorporated in 1853.

The history and industrial growth of Bristol parallel that of Waterbury, although its industrial expansion occurred a little later. Early in the 19th century the clock-manufacturing companies, Ingraham and Sessions, were well established. In fact, the clockmakers founded the Bristol Brass Co. in the latter half of the 19th century to ensure a steady supply of brass. Since World War II, Bristol has become one of the centers of the precision mechanical-spring industry.

The economic growth of Connecticut has always exceeded that of New England generally, and indications are that the State will continue to grow in population and wealth. Connecticut is the most industrialized State in the Nation, and the Waterbury-Bristol area plays an important part in the State's manufacturing and commercial activity. Waterbury is the only city in the State (as distinct from suburbs) which did not experience a net decrease in population in the decade from 1950 to 1960. It actually showed a net increase of 2.5 percent, while suburban areas of the city increased from 100 to 140 percent. The population of Bristol is now about 46,000, an increase of 26.5 percent in the last 10 years. The total population of the Waterbury-Bristol area increased from 30,300 in 1880 to 170,000 in 1960.

In 1960 there were about 450 manufacturing establishments in the area, about three-fourths of which were in Waterbury itself. Three great brass companies—Chase, American, and Scovill—have given Waterbury the name of "the Brass City." The primary industry was and is brass and brass products, but the factories of Waterbury also make copper and copper products, clocks, watches, timing devices, recording instruments, tools, ladies' undergarments, plastics, leather belting, wood and cardboard cartons, screw machine products, electronic devices, novelties, pins, and paper clips.

Stability and diversity are characteristics of Bristol industry. Among the larger industries are Superior Electric Co., which is the third largest employer in Bristol, the Hildreth Press, the H. J. Mills Co., which makes paper boxes, and the Bristol Machine and Tool Co.

The early industrial growth of the Waterbury-Bristol area was chiefly the result of the availability of an abundant water supply. Heavy industries use large quantities of water, and a dependable supply of good quality from the Naugatuck and Pequabuck Rivers in part determined the choice of location for these plants and fostered the growth of many other industries. This later diversification brought about changes in water requirements and led to problems of quantity and quality of the water supply which may affect the future growth of the area.

SOURCES OF WATER

Precipitation in its various forms—rain, snow, sleet, and hail—is the source of all water in the Waterbury-Bristol area. After it falls, part collects in lakes and ponds or flows off in rivers and brooks, part soaks into the ground and moves by gravity downward to saturate the

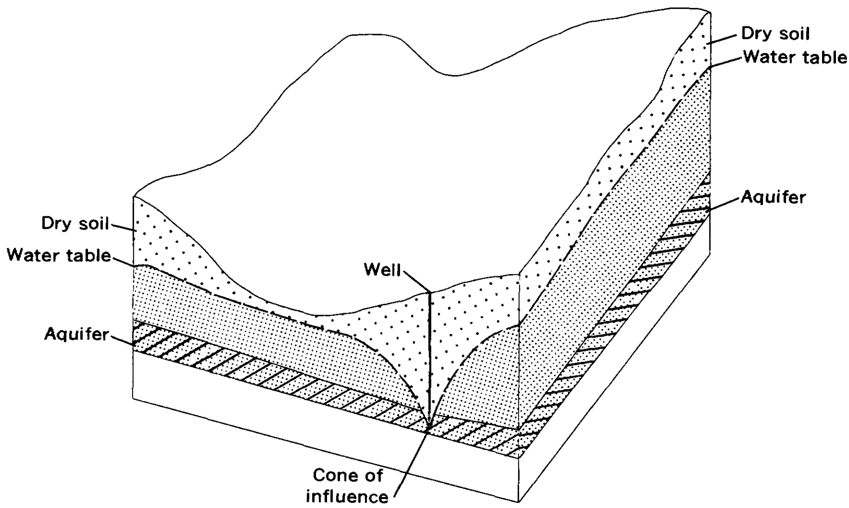


FIGURE 2.—Water table and aquifer.

rocks below the surface, and part is returned to the atmosphere by evaporation or by transpiration from vegetation. The top of the zone of water-saturated rocks is called the "water table" (fig. 2). A layer of rock that yields water in useful quantities is called an "aquifer."

The separate terms "surface water" and "ground water" are used to describe the source of the water, not to indicate different kinds of water. Both originate from precipitation and they are interrelated. Some ground water seeps into river channels and becomes surface water, maintaining the flow of streams during periods of no precipitation. Under certain conditions, surface water moves toward the cone of depression around a pumped well near a stream and becomes a part of the ground water, helping to sustain the long-term yield of the well.

Precipitation in the Waterbury-Bristol area averages about 50 inches annually, considerably above the annual average of 30 inches for the United States as a whole. It is well distributed throughout the year.

Streamflow is plentiful, and ground water is available in many places in small to moderate quantities. However, water supplies are not plentiful in some parts of the area. There are several reasons why water supplies may be scarce even in an area where rainfall is abundant and rivers and lakes are accessible. A new suburb or industry may want water where it is already appropriated for some other use. There may be no surface or underground storage to hold surplus water until it is needed. The streams may be so polluted they are unfit for a particular use. Large quantities of water alone are not enough. Distribution, storage, and quality control are problems which exist even where there are great rivers close by.

The principal sources of surface water are the main stem and tributaries of the Naugatuck River and the Pequabuck River (fig. 1). They are capable of supplying the needs of the area for many years to come, but pollution restricts use without treatment. Ground water occurs in practically all the rocks of the area. The largest supplies are developed from wells tapping sand and gravel aquifers, but these aquifers are not widespread. Small supplies sufficient for domestic use can be developed from the bedrock which underlies the entire area.

SIGNIFICANCE OF WATER QUALITY

Questions arise about the chemical quality whenever the use of a water supply is considered. What are the quantities and kinds of material in solution in the water? What are the chemical and physical effects caused by the dissolved material? The answers to these questions are important.

Water that contains a large amount of calcium and magnesium is called hard water. Hard water is objectionable for domestic use because excessive amounts of soap are required to make a lather. When hard water is used for industrial purposes, it leaves a scaly deposit on the inside of boilers and tanks. We measure the amount of dissolved solids in water in parts per million; 10 ppm (parts per million) would mean 10 pounds of dissolved matter to a million pounds of water. More than 60 ppm of calcium and magnesium would be moderately hard water, and more than 180 ppm would be excessively hard water.

Another quality in water which must be considered is the balance between alkalies and acids. This balance is known as the pH value. A pH value of 7 indicates neutral water. Above a pH of 7, the water is alkaline; below 7, it is acid. Alkaline water will leave deposits on metal and porcelain; acid water is corrosive. Good water should be nearly neutral.

Iron and manganese concentrations in excess of about 0.3 ppm (0.00003 of 1 percent) will discolor laundry and will deposit on utensils. In the manufacture of fabrics or paper, the same effects will occur. Acid water will cause corrosion in distribution systems. Water with excessive amounts of alkalies, bicarbonate and chloride is unsuitable for irrigation. These are only a few examples, but they show clearly that the utility of water supply depends, in part, on its quality.

TABLE 1.—*Suggested water-quality tolerances*

[After Moore (1940). Allowable limits in parts per million. Other requirements: P indicates that potable water, conforming to U.S. Public Health standards, is necessary]

Industry or use	Turbidity	Color	Hardness as $CaCO_3$	Iron as Fe	Manganese as Mn	Iron+manganese Fe+Mn	Total solids	Alkalinity as $CaCO_3$	Odor, taste	Hydrogen sulfide	Other requirements
Air Conditioning				0.5	0.5	0.5			Low	1	No corrosiveness or slime formation.
Baking	10	10		.2	.2	.2			do	.2	P.
Brewing:											
Light beer	10			.1	.1	.1	500	75	do	.2	P; NaCl, <275 ppm, pH 6.5–7.0.
Dark beer	10			.1	.1	.1	1,000	150	do	.2	P; NaCl. <275 ppm, pH, 7.0 or more.
Canning:											
Legumes	10		25–75	.2	.2	.2			do	1	P.
General	10			.2	.2	.2			do	1	P.
Carbonated beverages	2	10	250		.2	.3	850	50–100	do	.2	P: organic color plus oxygen consumed, <10 ppm.
Confectionery				.2	.2	.2	100		do	.2	P; pH, >7.0 for hard candy.
Cooling	50		50	.5	.5	.5				5	No corrosiveness or slime formation.
Food processing (general)	10			.2	.2	.2			Low		P.
Ice making	5	5		.2	.2	.2			do		P; SiO_2, <10 ppm.
Laundering			50	.2	.2	.2					
Plastics (clear, uncolored)	2	2		.02	.02	.02	200				
Paper and pulp:											
Groundwood	50	20	180	1.0	.5	1.0					No grit or corrosiveness.
Kraft pulp	25	15	100	.2	.1	.2	300				
Soda and sulfite pulp	15	10	100	.1	.05	.1	200				
High-grade light papers	5	5	50	.1	.05	.1	200				
Rayon (viscose):											
Pulp production	5	5	8	.05	.03	.05	100	Total 50; hydroxide 8.			Al_2O_3, <8 ppm. SiO_2, <25 ppm. Cu, <5 ppm. pH, 7.8–8.3.
Manufacture	.3		55	.0	.0	.0					
Tanning	20	10–100	50–135	.2	.2	.2		Total 135; hydroxide 8.			
Textiles:											
General	5	20		.25	.25						
Dyeing	5	5–20		.25	.25	.25	200				Constant composition; residual alumina, <0.5 ppm.
Wool scouring		70		1.0	1.0	1.0					
Cotton bandages	5	5		.2	.2	.2			Low		

The uses of water are many, and it would be impossible to devise a single standard which will meet all chemical and sanitary specifications. However, water-quality standards have been established for domestic, industrial, and other uses. For example, water used in the manufacture of foods and beverages must be clear, colorless, and free from tastes and odors. Suggested water-quality tolerances for some of the major industries are shown in table 1.

Water is suitable for irrigation if it is relatively free of toxic substances such as boron and does not contain excessively large quantities of solutes. Small quantities of boron are necessary for plant growth, but a concentration in excess of 1.0 ppm could be detrimental to some plants. The concentration of dissolved solids also is important, but a wide range is permissible. For example, a water having a dissolved-solids content as high as 1,200 ppm will have negligible effect on crops (Richards, 1954, p. 60). So far as is known, all natural waters in the Waterbury-Bristol area contain less than 1,200 ppm dissolved solids.

The standards for domestic purposes are stringent. In 1962, the U.S. Public Health Service established standards for drinking water that apply to water supplies used in interstate carriers. These standards are generally accepted for public water supplies.

	Mandatory limits (ppm)
Lead	0.1
Arsenic	.05
Selenium	.01
Chromium (hexavalent)	.05
Fluoride:	
Lower limit	.8
Optimum	1.0
Upper limit	1.3

	Recommended limits (ppm)
Copper	1.0
Iron	.3
Manganese	.05
Zinc	5.0
Chloride	250
Sulfate	250
Phenolic compounds	.001
Dissolved solids:	
Recommended	500
Permissible	1,000

Pollution of surface water adds to the problem of water management. As the demand for water increases because of population growth and industrial development, municipalities without adequate reserves are forced to go a considerable distance to obtain additional water. Yet a potential source of supply may be readily available. In the Waterbury-Bristol area, the Naugatuck River would be a source of water for public supply if the pollution problem could be solved.

The New England Interstate Water Pollution Control Commission has published tentative standards for examination and classification of surface waters (table 2). These standards were adopted by the Connecticut Water Resources Commission for classifying streams in the State.

TABLE 2.—*Classification of surface waters according to suitability of use*

[New England Interstate Water Pollution Control Comm., tentative plan for classification of waters]

Impurities	Class A	Class B	Class C	Class D
Suitability [1]				
	Any water use. Character uniformly excellent.	Bathing and recreation, irrigation, and agriculture; good fish habitat; good esthetic value. Acceptable for public water supply with filtration and disinfection.	Recreational boating; irrigation of crops not used for consumption without cooking; habitat for wildlife and common food and game fishes indigenous to the region.	Transportation of sewage and industrial wastes, without floating solids or odor; and for power, navigation, and other industrial uses.
Standards of quality				
Dissolved oxygen	Not less than 75 percent saturation.	Not less than 75 percent saturation.	Not less than 5 ppm	Present at all times.
Oil and grease	None	No appreciable amount	Not objectionable	Not objectionalbe.
Odor, scum, floating solids, or debris.	do	None	None	Do.
Sludge deposits	do	do	do	Do.
Color and turbidity	do	Not objectionable	Not objectionable	Do.
Phenols or other taste producing substances.	do	None	None	Do.
Substances potentially toxic	do	do	Not in toxic concentrations or combinations.	Not in toxic concentrations or combinations.
Free acids or alkalies	do	do	None	Not in objectionable amounts.
Coliform bacteria	Within limits approved by State Department of Health for uses involved.[2]	Bacterial content of bathing waters shall meet limits approved by State Department of Health and acceptability will depend on sanitary survey.		

[1] Waters falling below these standards are considered as unsatisfactory and as class E waters. These standards do not apply to conditions brought about by natural causes. Waters used or proposed for public water supply shall be so designated.

[2] Sea water used for market shellfish shall not have a median coliform content in excess of 70 per 100 ml.

Pollution is not restricted to surface water. Ground-water supplies in local areas may become polluted by drainage from septic tanks, a condition sometimes first revealed by the discovery of detergents in well water. Sand and gravel aquifers bordering polluted streams may be contaminated by infiltration of surface water. Contamination of some ground-water sources adjacent to the Naugatuck River is discussed later in the report.

PUBLIC WATER SUPPLY AND USE

WATERBURY SUBAREA

Most people, when they think about water supply and distribution at all, think about their municipal supply. This is natural; their municipal system supplies the water for their homes, schools, libraries, and fire departments. They may not even be aware that many industries, farms, and suburban homes are supplied outside the public system from other sources. More than half of all the water withdrawn in the area is used by industry. Even within the municipal system of Waterbury, 20 percent of the demand is supplied to industry.

The principal source of water for the Waterbury municipal water-supply system (table 3, fig. 3) is a chain of three reservoirs on Branch Brook, which enters the Naugatuck River near Thomaston, 5 miles north of the center of Waterbury. These three reservoirs, known as Pitch, Morris, and Wigwam, have a total capacity of 4,130 million gallons. Supplemental storage is available in Shepaug Reservoir (capacity, 576 million gal.). This reservoir is across the divide in the Shepaug River basin and is connected to Pitch Reservoir by a diver-

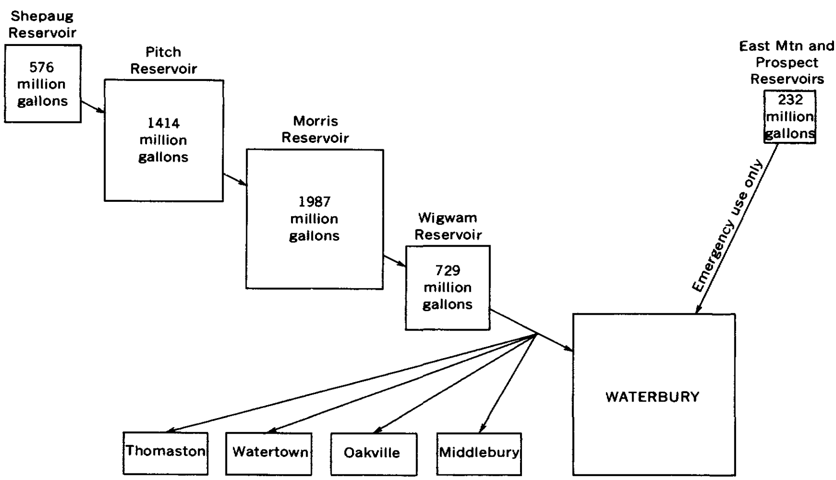


FIGURE 3.—Flow chart of water-supply system, city of Waterbury.

TABLE 3.—*Public water-supply systems*

Public supply system	Population served (1959)	Source of water	Raw-water storage		Treated water storage (million gal.)	Treatment	Daily use in 1959		
			Percent	Million gallons			Maximum (mgd)	Average (mgd)	Average per capita (gpd)
Bristol	45,000	Streams Wells	70 30	1,221	2.4	Coagulation, rapid sand filtration, chlorination.	5.7	4.9	109
Terryville	5,300	Wells Streams	85 15	19.1	0	Chlorination		.3	61
Waterbury	106,000	Streams impounded in Shepaug, Morris, Pitch, and Wigwam Reservoirs.		4,706	4	Chlorination, lime for pH adjustment.	21.6	14.9	141

sion tunnel. Southeast of the city are smaller reservoirs known as East Mountain and Prospect with a combined capacity of only 232 million gallons. These two small reservoirs are now used only for emergency purposes. This reservoir system provides a dependable supply, and since its completion in January 1944 has never had less total storage than the 3,000 million gallons in the reservoirs at the end of October 1957.

The Water Department of the city of Waterbury serves the entire population within the city limits (107,130 persons in 1960) except for a small area in the southern part which is served by the Naugatuck Division of the Connecticut Water Co. and a few small areas served by individual wells. It also supplies small areas in Thomaston, Oakville, Watertown, and Middlebury with an average in 1959 of about one-third of a million gallons per day. In 1959 the city provided water to its customers at a rate of 14.1 mgd (million gallons per day), and the Connecticut Water Co. supplied about 0.8 mgd. This total rate of 14.9 mgd is equivalent to a requirement of 140 gallons per capita per day. The population of Waterbury increased from 104,477 in 1950 to 107,130 in 1960, while the rate of consumption of water increased from about 13 mgd to about 15 mgd, or approximately 15 percent (fig. 4). This represents a per capita increase in use from about 125 gpd (gallons per day) in 1950 to about 140 gpd in 1959.

During the years 1957 through 1959, the Water Department of the city of Waterbury supplied, on the average, 56 percent of its total demand to domestic and commercial users, 20 percent of its demand to

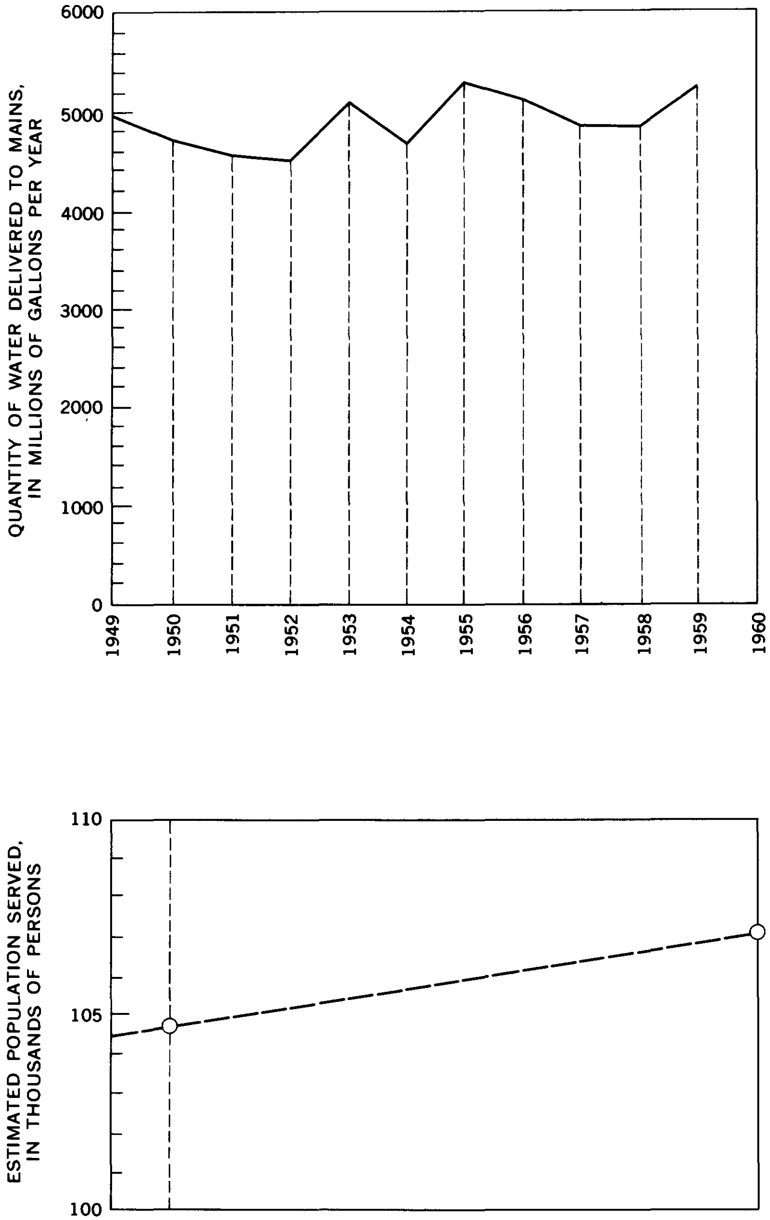


FIGURE 4.—Quantity of water distributed by Waterbury Water Department, 1949–59.

industrial users, and 24 percent of its demand for municipal purposes. The water supplied to industry was used primarily for sanitary purposes, only a small part being used in manufacturing processes.

Seasonal fluctuations in demand on the Waterbury public water-supply system, averaged over the period 1950–59, are shown in figure 5 as percentage of average monthly demand. The extreme range is from 92 percent in April to 115 percent in August.

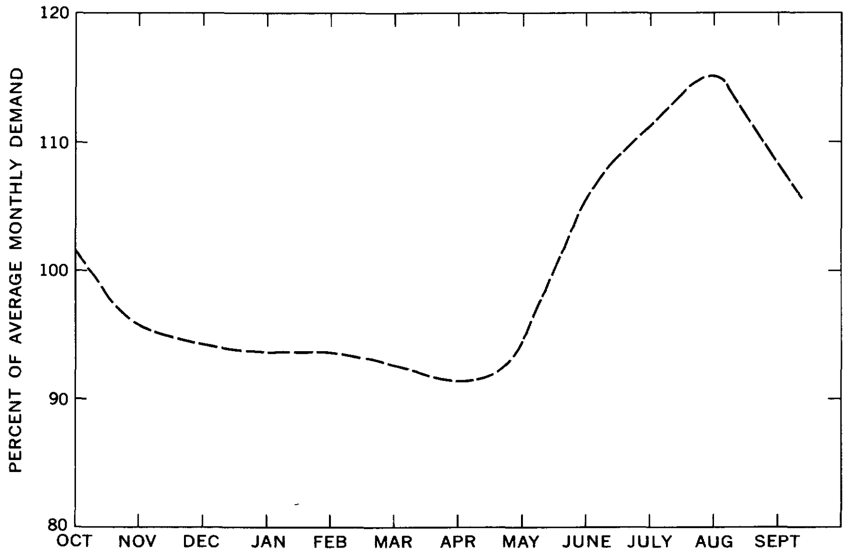


FIGURE 5.—Percentage of average monthly demand for water supplied by the Water Department of the city of Waterbury, 1950–59.

The chemical quality of the water furnished to consumers in Waterbury is excellent. Dissolved solids range between 40 and 60 ppm (table 4). The principal chemical constituents are calcium, bicarbonate, and sulfate. Other chemical constituents normally present in water were low. For example, the iron content was only 0.12 ppm. Because of the low content of calcium and magnesium, the hardness of the water from the Waterbury supply varied between 24 and 31 ppm. Purification and chemical treatment of the raw water is limited to chlorination and addition of lime to adjust the pH. In treated water from the Waterbury supply, the pH ranged between 6.4 and 6.8 units, almost neutral.

Water from the Waterbury supply is satisfactory for all domestic and most industrial uses.

TABLE 4.—*Chemical analyses, in parts per million, of water from public water-supply systems in the Waterbury-Bristol area*

System	Bristol		Terryville	Waterbury	
Date of collection	July 12, 1951	Apr. 3, 1960	Apr. 3, 1960	June 25, 1952	Mar. 30, 1960
Silica (SiO_2)	4.3		6.2	2.8	
Iron (Fe)	.04	0.15	.18	.12	0.14
Manganese (Mn)	.00		.11		
Calcium (Ca)	2.8		3.5	7.5	
Magnesium (Mg)	1.0		1.8	1.3	
Sodium (Na)	5.4			2.0	
Potassium (K)	.3			.9	
Bicarbonate (HCO_3)	9	10	6	17	18
Sulfate (SO_4)	11	16	13	9.0	12
Chloride (Cl)	2.8	4.0	3.8	5.5	5.8
Fluoride (F)	.1		.1	.0	
Nitrate (NO_3)	.3		.4	.1	
Dissolved solids: Residue at 180°C	34	44	37	42	55
Hardness as $CaCO_3$:					
Calcium, magnesium	11	16	16	24	31
Noncarbonate	4	8	11	10	16
Specific conductance (micromhos at 25°C)	54.8	70	51	67.4	86
pH	6.5	6.3	6.4	6.8	6.4
Color units	1		10	4	

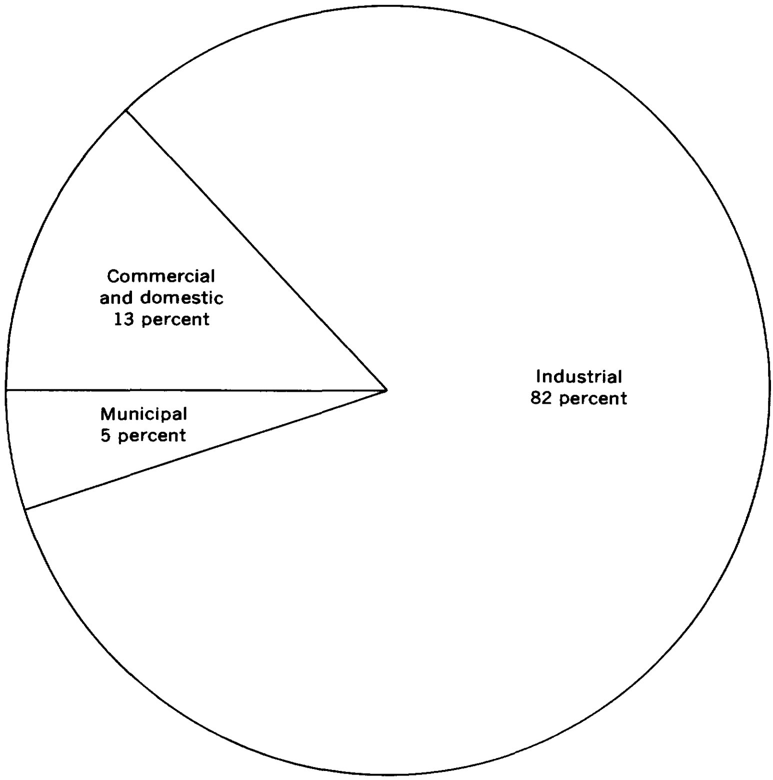
The average amount of water used in 1959 from public and private services in the Waterbury subarea was estimated to be 70.0 mgd. Table 5 and figure 6 summarize this use by type of use and source of supply; they show that 57.5 mgd or 82 percent of the total water withdrawn was required to satisfy the needs of industry, 9.3 mgd or 13 percent for domestic use, and 3.2 mgd or 5 percent for municipal purposes. About 96 percent of all water used was from surface sources. The remaining 4 percent was pumped from wells.

The data in table 5 are given as average use in millions of gallons per day for 1959. This method of reporting may be somewhat misleading unless it is realized that water use fluctuates greatly with the seasons. Maximum daily use for all purposes occurs during the sum-

TABLE 5.—*Average use of water, in million gallons per day, in the Waterbury subarea, 1959*

Use	Supply			Total	Percent of total
	Public (all from surface sources)	Private			
		Surface water	Ground water		
Domestic and commercial [1]	9.3			9.3	13
Industrial [2]	2.4	52.6	2.5	57.5	82
Municipal and leakage	3.2			3.2	5
Total	14.9	52.6	2.5	70.0	100

[1] Population served about 106,000.
[2] Includes water for air conditioning.



TOTAL WATER USE IN 1959 ABOUT 25.55 BILLION GALLONS
(EQUIVALENT TO AN AVERAGE OF 70.0 MGD)

FIGURE 6.—Use of water in the Waterbury subarea, 1959.

mer. For example, the use of water for cooling by commercial and industrial establishments and for domestic use reaches a maximum during the summer months, and the entire load of water use for air conditioning is concentrated in this same period. Therefore, the maximum and also the minimum daily use in the area depart considerably from the average daily use.

Industry in the Waterbury area uses water for cooling and processing, for boiler feed, and for sanitary services. Its greatest use is in the fabrication of copper tubes, sheets, and shapes. Most of this water comes from private supplies, 95 percent of which have their source in nearby streams. The major use of this water is for cooling, and it is immediately returned to the streams unchanged in quality, but at a slightly higher temperature. The same is true of water used from ground-water sources although the water is discharged into surface channels. Except for a small amount of air conditioning, use of water for industrial purposes probably has little seasonal fluctuation.

BRISTOL SUBAREA

The city of Bristol has an ample supply of water for its present and future needs. Six reservoirs northwest of downtown Bristol in Harwinton, and Plymouth impound water from a drainage area of 9.6 square miles. (A seventh reservoir is in the planning stage.) Their total storage capacity is 1,221 million gallons (fig. 7). Usually the full storage capacity is not utilized except during heavy precipitation and runoff. A dependable yield of 7.2 mgd can be obtained from the watershed, even during the driest weather. In addition to the six reservoirs, the Bristol municipal water system includes an auxiliary ground-water supply consisting of two gravel wells, which have a dependable yield of 3 mgd. On the basis of an average use of 5 mgd in 1959, sufficient water is available for current and future needs. However, plant capacity would be a limiting factor if water requirements should increase substantially. Currently, the rated capacity of the treatment plant is 5 mgd with a maximum capacity of 8 mgd. Additional information on the Bristol supply appears in table 3.

The chemical quality of the Bristol municipal water supply is excellent. Dissolved solids are about 40 ppm (table 4). Hardness of the water is only 11 to 16 ppm—much less than the average hardness of 30 ppm for 23 major water supplies in Connecticut given by Lohr and Love (1954, p. 23).

A smaller water supply owned and operated by the Terryville Water Co. furnishes water to Pequabuck and Terryville. Eighty-five percent of the water supply is obtained from wells and 15 percent from impounded streams. The ground-water supply alone is sufficient for current and future use. It consists of two wells having a combined dependable yield of 1.1 mgd. About 0.1 mgd of water can be obtained from streams. Thus, a total of 1.2 mgd is available. Of this total, only an average of 0.32 mgd was used during 1959. Additional information is presented in table 3.

The quality of the Terryville water supply is considered excellent. The dissolved solids content of a water sample collected April 3, 1960, was 37 ppm, and the hardness of the water was 16 ppm (table 4).

The total amount of water used in the Bristol subarea in 1959 was approximately 2.5 billion gallons. The sources and distribution of the water used are summarized in figures 8–11 and table 6. As may be seen from these illustrations, both private and industrial supplies and public supplies were obtained primarily from surface reservoirs and streams. More than half the water was used by industry, in the manufacture of ball bearings, brass metal stock, clocks, electrical equipment, locks, and other products.

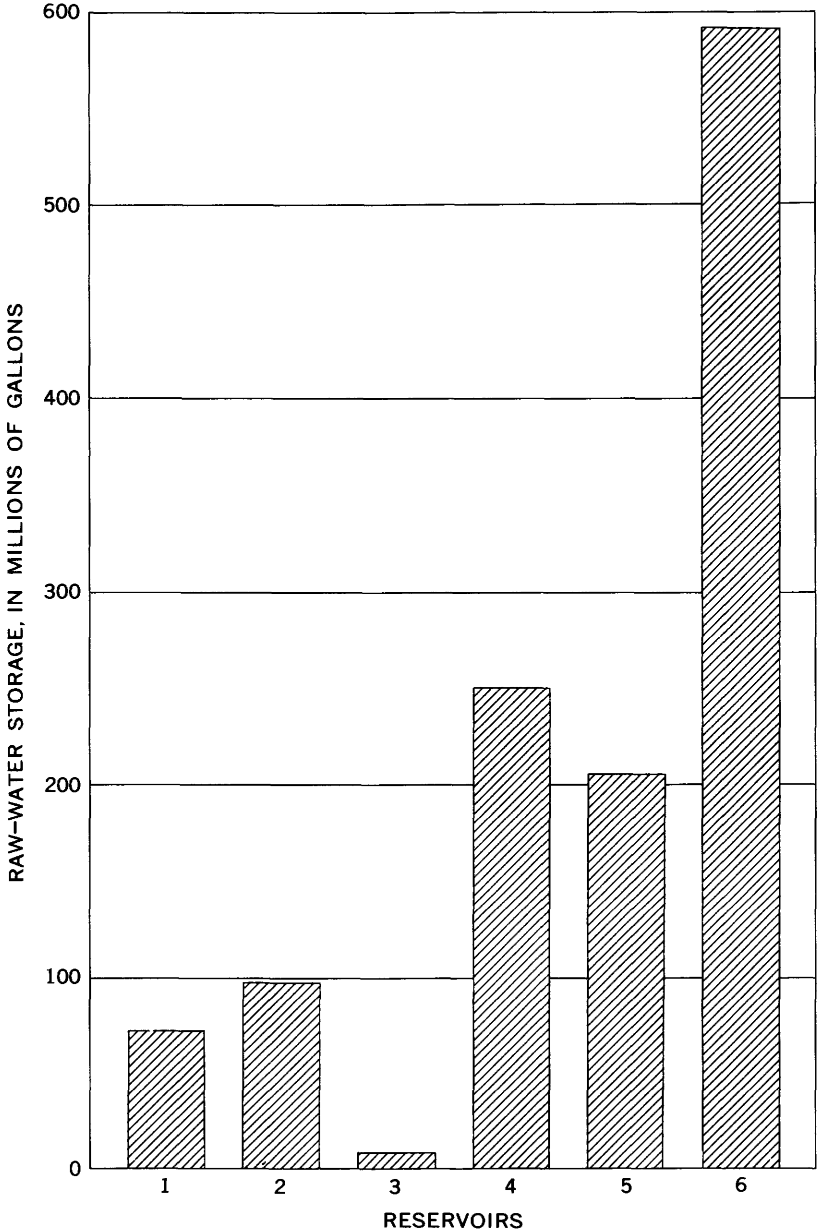


FIGURE 7.—Raw-water storage, Bristol water system.

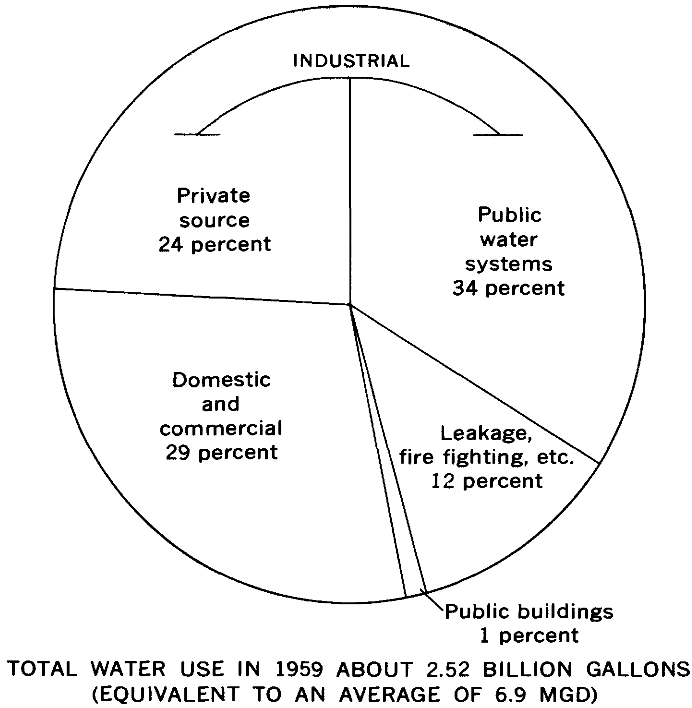


FIGURE 8.—Use of water in the Bristol subarea, 1959.

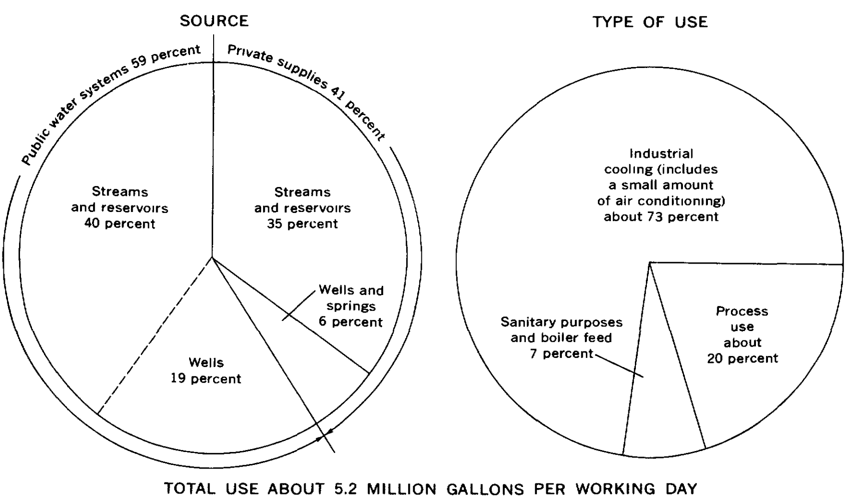


FIGURE 9.—Source and use of water by industry in the Bristol subarea, 1959.

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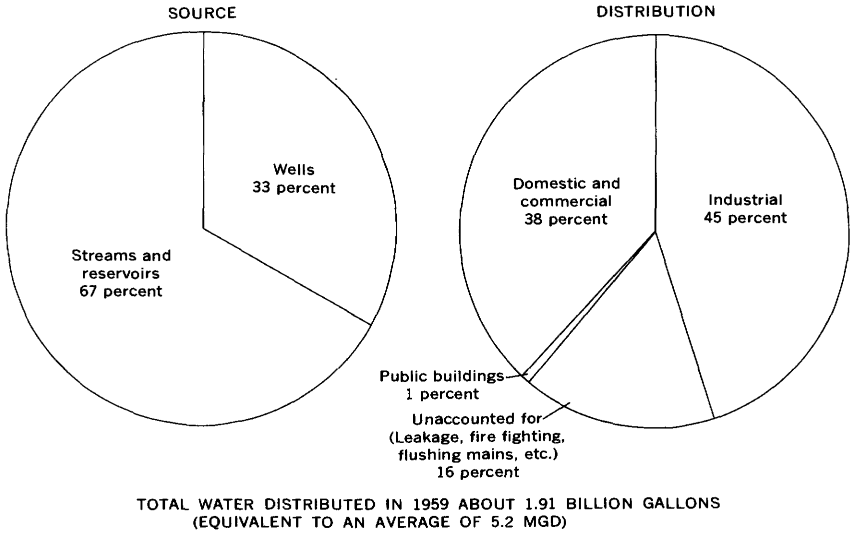

Figure 10.—Source and use of water distributed by public water systems in the Bristol subarea, 1959.

Water use by industry was computed to be approximately 5.2 million gallons per working day. By far the largest part of this water was used for industrial cooling in jackets, coils, or heat exchangers. A smaller quantity of water was devoted to various process uses, including makeup of solutions, rinsing, washing, beverage bottling, and types of cooling in which metal products were sprayed or immersed in water. Other uses were for drinking, lavatories, and boiler makeup. These three categories of industrial use differ in their requirements for and effects on water quality. Water used for industrial cooling generally needs no special standards of chemical or bacterial quality. After use, the water is generally released to the Pequabuck River or its tributaries with no significant difference in chemical quality, though higher in temperature. Chemical and physical quality requirements for process water vary widely. Much of this water also is released to streams, commonly with increased mineral and (or) acid content. Boiler-makeup water and most lavatory and drinking water must meet strict quality standards; waste water from sanitary facilities is discharged to septic tanks or the Bristol sewer system.

Average daily water use values are given in table 6 and are included in figures 8 and 10. Actual daily water use, however, fluctuates considerably, particularly with the season. Maximum daily use is during the summer months. Domestic consumption increases in the summer owing to lawn watering and other outdoor uses. More water is used for industrial cooling in the summer because of the

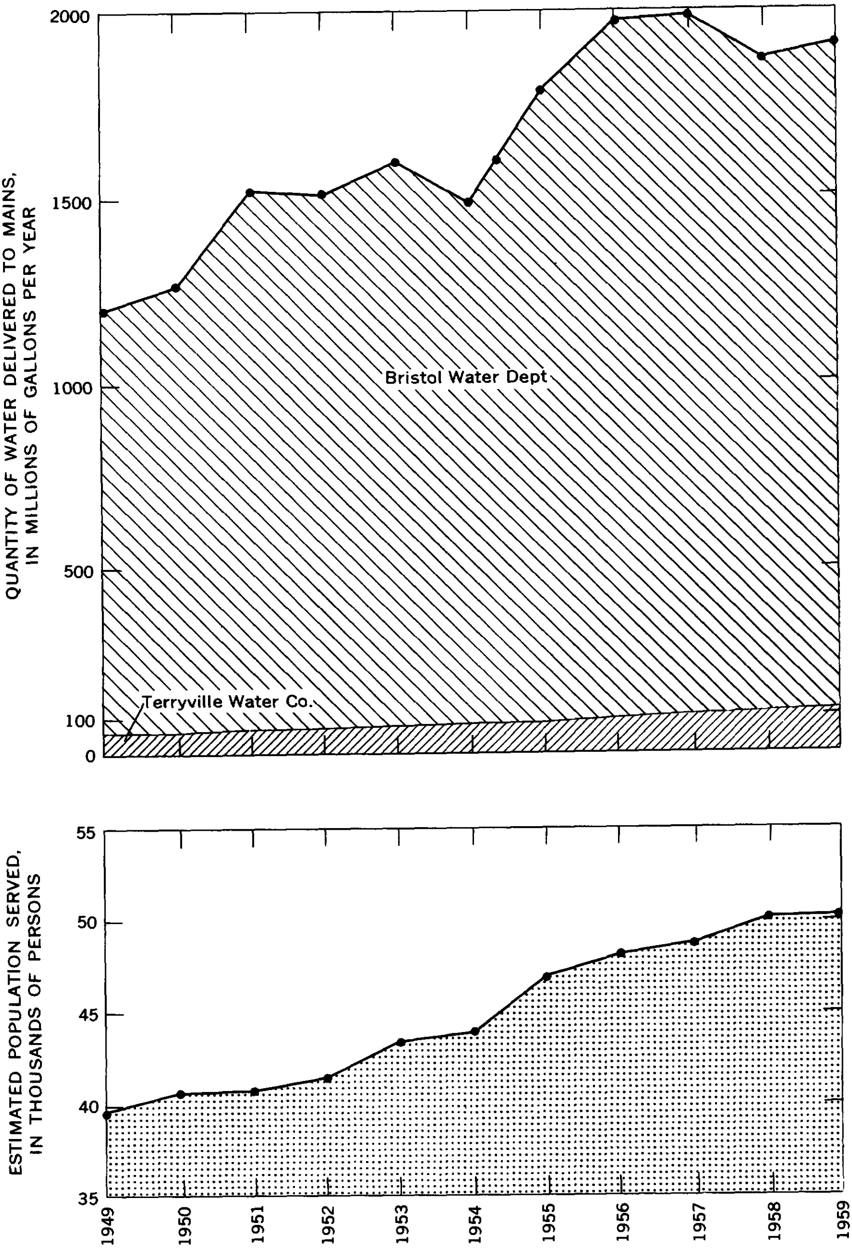

FIGURE 11.—Quantity of water distributed by public water systems in the Bristol subarea, 1949–59.

TABLE 6.—*Average use of water, in millions of gallons per day, in the Bristol subarea, 1959*

Use	Public supply		Private supply		Total	Percent of total
	Surface	Ground	Surface	Ground		
Domestic and commercial [1]	1.3	0.7			2.0	29
Industrial [2]	1.6	.7	1.5	0.2	4.0	58
Municipal and leakage	.6	.3			.9	13
Total	3.5	1.7	1.5	0.2	6.9	100

[1] Population served 50,300 (1959).
[2] Includes a small amount of water for air conditioning.

higher water temperature as well as air temperatures, and a small amount of water is used for air conditioning. Data collected by one large company which uses much water for cooling show that over a period of 5 years water consumption averaged 26 percent higher from May through October than from November through April. Fluctuation in rate of distribution by public water systems, which reflects fluctuation in demand by both domestic and industrial users, is given in the following table:

Water system	*Water distribution, in million gallons per day*		
	Average daily use for 1959	*Average day of minimum month*	*Average day of maximum month*
Bristol Water Department	4.9	4.6 (January 1959)	5.5 (September 1959)
Terryville Water Co	.32	.22 (April 1959)	.48 (May 1959)

The use of water for public supply in the Bristol subarea has increased fairly steadily in recent years, as shown in figure 11. This increase is due in part to the population growth of the area. However, the amount of water delivered to the water mains increased 59 percent from 1949 to 1959, while the population served increased only 26 percent (estimated). The difference doubtless is due to greater per capita domestic consumption and to additional use by industry.

RURAL SUBAREA

The total amount of water used in the Rural subarea in 1959 was estimated to be about 345 million gallons, or an average of nearly a million gallons per day. Nearly all was pumped from privately owned wells. Domestic use by persons not served by public water systems made up 96 percent of this total, commercial use about 2 percent, and industrial and agricultural use 1 percent each. Industry used nearly two-thirds of its water in process operations; most of the remainder was used for drinking, lavatories, and boiler makeup. Many of the small industrial establishments use water only for drinking and sanitation. Among the larger industrial water users are companies concerned with heat treating, food and beverage bottling, and manufacture of cleaning and buffing compounds.

Several industrial users reported using considerably more water in the summer than in the winter, and almost all use of water for agriculture was during the summer. No information on seasonal variations in commercial and domestic use was obtained, but presumably these uses also are greater during the summer.

EMERGENCY WATER SUPPLIES

Two basic considerations in a Civil Defense program are the safeguarding of water supplies against contamination and destruction and the planning for emergency water supplies in the event normal service is interrupted or destroyed. The following information is presented as an aid to Civil Defense officials in setting up emergency water systems in the Waterbury-Bristol area.

If a nuclear explosion were to occur in the area, a wide variety of problems involving water would develop. Among the more serious of these are radioactive contamination of water sources, destruction of water-treatment plants and distribution systems, and pollution of water supplies through breakage of water and sewer mains. If one or more of these problems were to arise, it would be necessary to supply the populace for an undetermined period of time from emergency sources which had not been seriously contaminated by radioactive fallout.

Of the possible water sources in the area, ground-water sources are least likely to be contaminated because they are not in direct contact with the atmosphere, and earth materials overlying the water-yielding units would serve to filter out much of the fallout. Because of this filtering action, water from wells with relatively deep casing, whether finished in sand and gravel or in bedrock, would be least subject to contamination. Numerous wells within the Waterbury-Bristol area have fairly substantial yields and could be used for emergency supplies. Some of them, however, are finished at shallow depths close to the banks of lakes or streams, so that if they were pumped heavily and continuously, a part of the water withdrawn would be water induced into the ground from the surface-water bodies. Records of large-capacity wells are given in table 7, and their locations are shown on plate 1. In addition, individual wells yielding at least a few gallons per minute supply most homes and businesses in rural sections of the Waterbury-Bristol area. Several such wells in a small area might be used together to provide an emergency supply. Of the rural wells, those tapping bedrock in areas where the glacial overburden is thick and bedrock outcrops are absent would be least likely to become contaminated.

TABLE 7.—*Records of wells selected as possible emergency water supplies (marked with asterisk,*) and other wells referred to in the text*

Locations of all wells are shown on plate 1.
Type of well: Dr, drilled; Du, dug.
Depth of well and depth of solid casing: All depths are below land-surface datum.
Use: Acc, air conditioning; Com, commercial; Dom, domestic; Ind, industrial; Obs, observation; Pws, community water supply; Test, test well: Un, unused.
Remarks: The word "Analysis" indicates that a chemical analysis is given in table 6 or 14.

Well	Owner	Location	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-yielding unit	Depth of solid casing (feet)	Static water level: Feet below land surface	Static water level: Date of measurement	Yield (gpm)	Drawdown (feet)	Specific capacity (gpm per ft)	Use	Remarks
Bristol														
Bs 3*	Johnny's Restaurant.	Central St	Dr	256	8	Sedimentary bedrock.	18	4	June 1954	110			Acc, Com	Bedrock at 17 ft.
4*	Bristol Water Dept.	Connecticut Route 72.	Dr	75	12	Sand and gravel.	55	6	Feb. 26, 1948	800	32	25	Pws	
46	L. D. Minor	Hill St	Dr	255	6	Crystalline bedrock.		60		5			Dom	Analysis.
78	N. Monbleau	Old Waterbury Rd.	Du	8	36	Sand and gravel.	8	6.3	Nov. 28, 1956				Dom	Do.
92*	Bristol Brass Corp.	do	Dr	40	30	do		7	1934	300	22	14	Ind	Owner's well No. 2; 4 similar wells nearby, not all in use; water has low pH, high sulfate content.
123*	Wallace Barnes Div., Associated Spring Corp.	do	Dr	39	10	do		8	1938	200	12	17	Un	Pump removed; formerly industrial use; present yield may be less than shown.
125	J. A. Anderson	Camp St	Dr	223	6	Sedimentary bedrock.		15	Dec. 5, 1956	10			Dom, Com	Bedrock at 27 ft.
147	Superior Electric Co.	Middle St	Dr	608	10	do	68	16	Nov. 1958	20	208	0.1	Un	Abandoned; bedrock at 55 ft.
148*	Bristol Water Dept.	Mechanic St	Dr	72	24–18	Sand and gravel.	52	2	Apr. 3, 1958	1,400	28	50	Pws	
149	do	Jerome St	Dr	38	8	do	28	4	Jan. 7, 1958	300	11	27	Test	
150	do	Mix St	Dr	45	8	do	35	1	Dec. 23, 1958	300	20	15	Test	
198*	Bristol Brass Corp.	Connecticut Route 72.	Dr	41	8	do	29	9	Nov. 4, 1953	150	14.4	10.4	Ind	

212*	New Britain Water Dept.	Maltby St	Dr	34	8	Sand and gravel.	19						Pws	One of 20 similar wells, part of White Bridge development; yield depends substantially on induced recharge.
214*	do		Dr	25	8	do							Pws	Northernmost of 6 similar wells in Upper White Bridge development.
220*	Superior Electric Co.	Middle St	Dr	32	18	do	24	14	Aug. 1960	150			Acc Ind	Pumping test 99 days.
221*	do	do	Dr	35		do	25	14	do	250			Acc Ind	Pumping test 44 days.
						Plymouth								
Pm 1*	Terryville Water Co.	Connecticut Route 72.	Dr	67	26	Sand and gravel.	52	3	Dec. 21, 1925	438	38	12	Pws	
2*	do	do	Dr	59	12	do	49	6	1953	488	33	15	Pws	
10*	E. E. Freimuth Dairy.	U.S. Route 6	Dr	309	8	Crystalline bedrock.	40	5		55			Com Acc	
						Waterbury								
Wb 3a*	Scovill Manufacturing Co.	East Main St	Dr	35	10	Sand and gravel.	27	9	1942	225	19	12	Ind	Analysis; well in building 143; water pumped to building 109.
10a*	Thinsheet Metals Co.	Railroad Hill St.	Dr	45	12	do	33	18	Sept. 2, 1943	750			Ind	Analysis; pump capacity 250 gpm; pump runs continuously.
11*	Plume & Atwood Mfg. Co.	Bank St	Dr	55	10	do	47			700			Un	Two similar wells nearby yielded 200 and 300 gpm, all 3 discharged into cistern; analysis (water from cistern) wells unused since 1955.
12	Waterbury Steel Ball Co.	East Aurora St.	Dr	75		Sand and gravel.				25			Ind	Analysis.

TABLE 7.—*Records of wells selected as possible emergency water supplies (marked with asterisk*) and other wells referred to in the text*—Continued

Well	Owner	Location	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-yielding unit	Depth of solid casing (feet)	Static water level		Yield (gpm)	Drawdown (feet)	Specific capacity (gpm per ft)	Use	Remarks
								Feet below land surface	Date of measurement					
Waterbury—Continued														
Wb 16*	Chase Brass & Copper Co.	Thomaston Ave.	Dr	84	8	do	72	16	1928	870			Ind	Analysis; pump capacity 600 gpm; pump runs continuously; a shallower well nearby supplies 250 gpm.
17*	do	do	Dr	69	10	do	34			400			Ind	Analysis; pump capacity 300 gpm; screened from 34 to 42 ft; bedrock at 42 ft.
18*	Chromium Corp. of America.	Huntington Ave.	Dr	80	10	do	72			150		2	Ind	
27*	Roger Smith Hotel.	West Main St.	Dr	200	10	Crystalline bedrock (?)				65			Acc	
28*	American Fastener Co.	Maple St.	Dr	32	60	Sand and gravel.				90			Ind	
38*	General Baking Co.	Robinson St.	Dr	260	8	Crystalline bedrock.	35			60			Ind	Bedrock at 25 ft.
52*	Patent Button Co.	Brown St.	Dr	175	8	Sand and gravel and crystalline bedrock.	64	47	1940	90			Ind	Bedrock at 57 or 70 ft; well at rear of plant, near Savings Street.
53*	State Theater	East Main St.	Dr	125	8	Crystalline bedrock.				150			Acc	Bedrock at 30 ft.
62*	7-Up Bottling Co.	South Main St.	Dr	265	8	do		14		55			Com	
65*	Eyelet Specialty Co.	State St.	Dr	72	4	Sand and gravel.	52	27	1941	100			Ind	

93	Mrs. William Nichols.	Pearl Lake Rd.	Du	33	48	do	None	24 28.5	Apr. 1, 1953 Sept. 26, 1957				Obs	U.S. Geol. Survey observation well 1944–1960; water levels shown are highest and lowest of record.
176	Mrs. Frank Bergin.	Scott Rd	Du	16	30	Ground moraine.	None	2.7 Dry	Jan. 30, 1958 Oct. 30, 1957				Obs	U.S. Geol. Survey observation well 1944–60; water levels shown are highest and lowest of record.
198	A. A. Baker	Pierpont Rd	Du	31	30	do	None	5.5 21	Jan. 10, 1946 Nov. 26, 1949				Obs	Do.
334*	Bristol Co	Bristol St	Dr	51	10	Sand and gravel.	31			200			Ind	Wb 334 and 335 pump into one pressure tank; analysis (water from tank).
335*	do	do	Dr	53	10, 12	do	46			140			Ind	Do.
339*	Connecticut Light & Power Co.	Eagle St	Dr	40	16	do		10	July 1957	400			Ind	Analysis; sulfate 130 ppm Jan. 28, 1960.
341*	Lea Manufacturing Co.	East Aurora St.	Dr	20		do		10	do	138			Acc Ind	Similar well nearby yields 80 gpm; total dissolved solids 332 ppm.
343*	Brock-Hall Dairy	do	Dr	74	6, 8	do		23	1945	200			Acc	
344*	Cly-Del Manufacturing Co.	Sharon Rd	Dr	35	8	do	25	3	Dec. 9, 1956	115	22	5	Acc	
345*	do	do	Dr	40	8	do	30	1	do	150	33	5	Un	No pump as of January 1960.
346*	do	do	Dr	44	8	do	34	5	do	250	21	12	Acc	
						Wolcott								
Wc 4*	National Die Co	Connecticut Route 69.	Dr	53	6	Crystalline bedrock.	26	9	1959	55			Ind	Bedrock at 7 ft.
12*	Wolcott High School.	Bound Line Rd.	Dr	376	8	do	42	13	Nov. 14, 1957	53	38	1.4	Pws	Bedrock at 14 ft.
14*	X-Tra Bottling Co.	Munson Rd	Dr	65	8	do		20		60			Com	Bedrock at about 30 ft.
16*	Chase Country Club.	East St	Dr	205	8	do	30	10	Apr. 1953	20	50	.40	Com	Bedrock at 20 ft.
19*	Scovill Mfg. Co	Nichols Rd	Dr	313	8	do	30	12	1944	15	106	.14	Com Dom	At Woodtick Recreation Area of Scovill Manufacturing Co.

Most of the wells in the Waterbury-Bristol area are equipped with pumps driven by electric motors, which could not operate in the event of a power failure. For this reason, wells designated by Civil Defense officials as emergency water supplies should be equipped with standby power facilities or auxiliary gasoline motors.

Small quantities of ground water could be developed easily in areas of sand and gravel by means of driven wells. Driven wells could be installed quickly with portable well-driving equipment and if fitted with hand pumps would not be dependent upon electric power. Safe emergency water supplies might be obtained in this manner where few existing wells are available. Driven wells could be completed successfully in most of the areas of sand and gravel shown on the geologic map (pl. 1). Relatively high terraces along valley margins should be avoided, as the deposits are largely above the water table and may contain many large stones which make driving difficult. Because of the variable lithology of the sand and gravel deposits, a certain percentage of the wells driven will end in fine-grained relatively impermeable deposits or hit large stones at shallow depth and be unsuccessful.

By contrast, surface-water sources, which are exposed to the atmosphere at all times, are especially subject to contamination from radioactive fallout. Local surface sources in which the water is held in more or less quiet storage, such as reservoirs and ponds, would be rendered useless for some time. However, the contamination in flowing streams would be reduced by dilution as radioactive particles are carried downstream or accumulate on bottom sediment, and ground water seeps into stream courses; thus the streams would gradually become usable for such purposes as fire fighting and the washing down of streets and buildings.

A LOOK AT THE FUTURE

All indications point to continuous increase of population and expansion of industry in the Waterbury-Bristol area in the next decade or two. In Waterbury the Scovill Manufacturing Co. is expanding its aluminum plant. The Waterbury Farrel Foundry and Machine Co. built a $2 million addition in 1961. A new $10 million shopping center in west-central Waterbury includes 20 acres of parking, 50 stores, a $2 million motor hotel, a medical-arts building, and 2 banks. The City Planning Commission has in the past 5 years recommended many zoning changes for light industry and has started an urban renewal program. Several industrial parks have been developed by private interests. One of these, the 58-acre Pierpoint Industrial Park, is a short distance from U.S. Interstate Highway 84 and has power, water, gas, and sewage facilities. Such parks, along with ample supplies of good water, may attract industrial concerns to Waterbury. In Bristol, too, expansion and development are taking place. Superior Electric has begun construction of a new, $3 million plant. An urban renewal project has been started.

Interstate Highway 84 and State Route 8 are to be relocated and designed to carry modern traffic loads. An interchange will be constructed in the center of Waterbury for easy ingress and egress. These highways will eventually connect with the New York Thruway and the Massachusetts and Connecticut Turnpikes, thus affording access to larger markets and making transportation of materials easier and cheaper.

All these construction and planning activities, plus a proposed urban renewal program, indicate a healthy economy and continued growth. They also indicate a possible future need for more sources of water.

According to the Connecticut Development Commission (1960), Waterbury has "one of the finest reserve watershed systems in the State, capable of considerable expansion." The Connecticut Water Resources Commission (1957, table 16) estimated demand for public water supply in the year 2000 and concluded, in regard to Waterbury, that "with some increased developments in sources of water supply, which have been considered for the future, it should be possible to meet the projected water-supply demands." A similar conclusion was reached in regard to north-central Connecticut, including Bristol. Existing public water-supply development for Waterbury on Branch Brook and for Bristol on Poland River has reached its ultimate capacity. Waterbury has already expanded its system to include a part of the Shepaug River basin adjacent to Branch Brook and has plans to increase storage capacity in that basin when necessary. Bristol may expand its system to include the upper part of Rock Brook, which is adjacent to the Poland River watershed.

Three large streams, tributary to the Naugatuck River in or near Waterbury, are potential sources of additional surface-water supply in the Waterbury subarea. Hancock Brook rises near Terryville and enters the Naugatuck River at Waterville just north of Waterbury. Water from this brook is little used at present. However, it has a drainage area of 14 square miles, and the streamflow from this basin would probably be proportional on a drainage area basis to that of Leadmine Brook near Thomaston, the records of which are analyzed in the inventory of water resources at the end of this report.

The second of the three streams is Mad River. This stream rises near Bristol and flows southwest through the heart of Waterbury. Its drainage area at the mouth is 27 square miles. The flow is completely controlled by the Scovill Manufacturing Co. through seven reservoirs in the basin. The downstream order and capacity of these reservoirs are:

	Gallons
Cedar Swamp Pond	370,000,000
Scovill (Woodtick) Reservoir	353,000,000
Hitchcock Lake, North	123,000,000
Hitchcock Lake, South	150,000,000
Chestnut Hill Reservoir	447,000,000
Brass Mill Pond	33,300,000
John D's Pond	4,500,000

Under normal operating conditions the rate of use of water from Mad River amounts to about 28 mgd, but about 95 percent of this is recirculated in winter and about 80 percent in summer through John D's Pond. Thus only a very small proportion of the total yield of the basin is used. The streamflow of Mad River per square mile of drainage area would probably be similar to that for Leadmine Brook near Thomaston.

Steel Brook, the third large tributary to the Naugatuck River in the Waterbury area, enters the river from the west passing through Watertown and Oakville before entering Waterbury. Its drainage area is 17.3 square miles. Although some water from this source is used in Watertown, Oakville, and western Waterbury, more could be utilized. The streamflow from Steel Brook can be approximated by comparison on a drainage area basis with records for Leadmine Brook near Thomaston.

Other possible sources of water in the Waterbury area are Lakewood Pond and Belleview Lake in the northern outskirts of Waterbury. These reservoirs drain southward through Great Brook, which passes underground in a conduit through the center of Waterbury. The ponds are controlled by the Chase Brass and Copper Co., which has little use for the water at the present time.

Water for some industrial uses is available in quantity from the Naugatuck River itself. Because of industrial pollution the quality of Naugatuck River water is not acceptable for other uses, but if the State's pollution abatement program is successful, it would be acceptable for many purposes.

Only a small fraction of the potential supply of ground water in the Waterbury-Bristol area has been developed. Large quantities of water are in storage in sand and gravel deposits, bedrock, and ground moraine, and the annual ground-water recharge is more than adequate to replace present annual withdrawal. The hydrograph (fig. 12) of well Wb 176, a dug well tapping ground moraine, illustrates the reliability of ground-water recharge year after year under natural conditions. Water levels normally decline from late March or April to

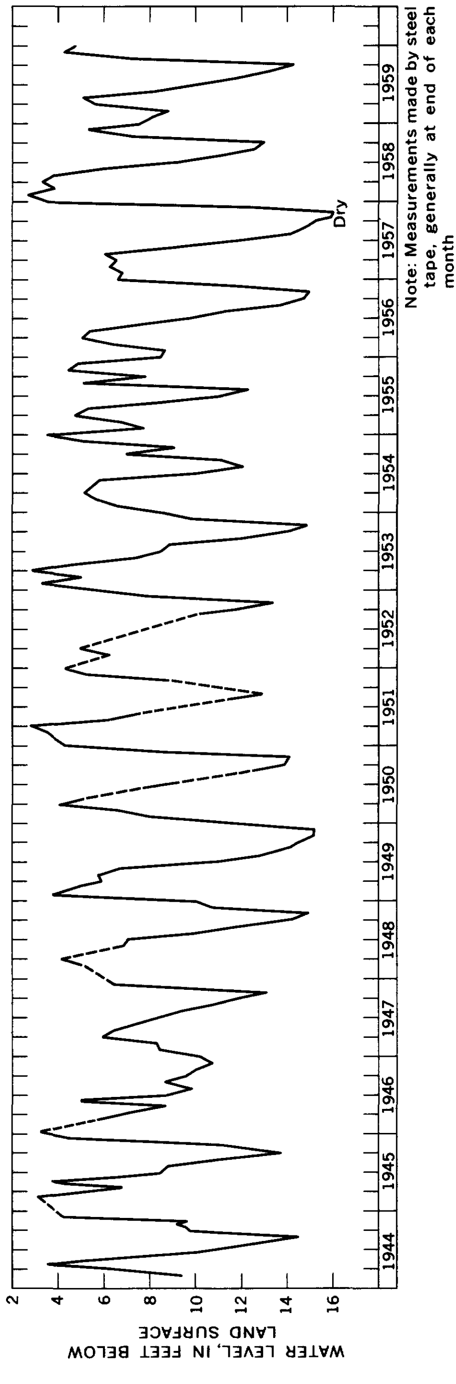

FIGURE 12.—Hydrograph of water levels in well Wb 176, 1944–59.

September, October, or November, but show a net rise from late autumn to early spring, when recharge from infiltrating precipitation exceeds use by plants. The hydrograph shows no long-term water-table decline, as water levels rise to about the same altitude every spring. If ground-water withdrawal were to increase in any locality to the point that pumpage plus natural ground-water discharge exceeded recharge, water levels would decline from year to year; as of 1959, no such localities are known in the Waterbury-Bristol area.

Domestic and small commercial supplies of at least 3 gpm are obtainable nearly everywhere from ground water. Supplies of this size can usually be obtained from the bedrock, or from sand and gravel or ground moraine where they are sufficiently thick. Quality of water may prove to be a problem in some upland areas where the ground moraine is less than 15 feet thick and may be interrupted by many bedrock outcrops. If numerous closely spaced homes served by septic tanks and by individual wells tapping bedrock are constructed in such areas, the chance of well pollution exists because contaminated septic-tank effluent may not be effectively filtered by the thin ground moraine and would have to move a considerable distance through the bedrock before being purified. Dug wells in such areas also could become contaminated, and might sometimes go dry. Large lot sizes, adequate spacing between wells and septic tank fields, and bedrock wells with 30 feet or more of casing cemented into the rock would reduce the chance of contamination.

Water supplies sufficient for a community of a few homes or for a small industry can generally be obtained from the bedrock. Single wells, however, rarely obtain more than 60 gpm (gallons per minute) from crystalline bedrock or more than 100 gpm from Triassic sedimentary bedrock. Furthermore, some wells drilled in bedrock intersect few fractures and yield only a few gallons per minute. Bedrock aquifers have not been overdeveloped anywhere in the Waterbury-Bristol area, as of 1959. Interference between wells would be kept to a minimum if new wells were placed at least a few hundred feet from existing large-capacity wells.

Yields of 100 gpm or more generally can be obtained only from wells in sand and gravel deposits in valley areas. The sand and gravel aquifers in the Waterbury-Bristol area are shown on the geologic map (pl. 1) and discussed in the inventory of water resources at the end of this report. The principal ones occur along the Naugatuck River, near the Mad River, in eastern Bristol, and in northwest-central Bristol and eastern Plymouth.

Water from the sand and gravel aquifers is generally low in mineral content, except possibly near large metal-fabrication plants where some downward seepage of highly mineralized wastes may occur. Steady pumping of large-capacity wells close to streams or lakes will induce infiltration of water from these surface bodies and increase well yield. Where streams carry considerable industrial waste, such induced infiltration will cause an increase in mineral content of the water pumped—a condition which prevails in several of the wells along the Naugatuck River as of 1959.

Evaluation of total ground water in storage in the sand and gravel aquifers and the safe perennial yield of each is beyond the scope of this report, but much greater development of each is possible even though large-capacity wells cannot be completed at every location. Areas most favorable for well construction and special problems pertaining to each aquifer are discussed in the inventory of water resources. In view of the steady suburban expansion in the Waterbury-Bristol area and the fairly small extent of the sand and gravel aquifers, it appears that unless testing for, and reservation of, sites for large-capacity community or industrial wells is carried out soon, most potential sites will probably be appropriated for urban development.

All water management involves such choices between present advantage and long-range benefit. The Waterbury-Bristol area has plenty of water available and many sources as yet undeveloped. The problem is how to have the right amount of water of the right quality for the intended use available where and when it is needed.

INVENTORY OF WATER RESOURCES

The availability and quality of water from surface and underground sources in the Waterbury-Bristol area are described on the following pages. Records of streamflow at sites on the Naugatuck River, Pequabuck River, and two smaller streams near the report area are analyzed. All important aquifers are shown on a map and evaluated. (See pl. 1.) Chemical analyses of water from wells and streams are presented and discussed. The section on the Waterbury subarea covers the Naugatuck River, Leadmine Brook, and several sand and gravel aquifers. The section on the Bristol subarea covers the Pequabuck River, Burlington Brook, two extensive sand and gravel aquifers, and the sedimentary bedrock aquifer in eastern Bristol. Ground moraine and crystalline bedrock underlie large parts of the Waterbury-Bristol area, but because they are the only aquifers in much of the rural subarea, they are described in that section along with a few small sand and gravel aquifers.

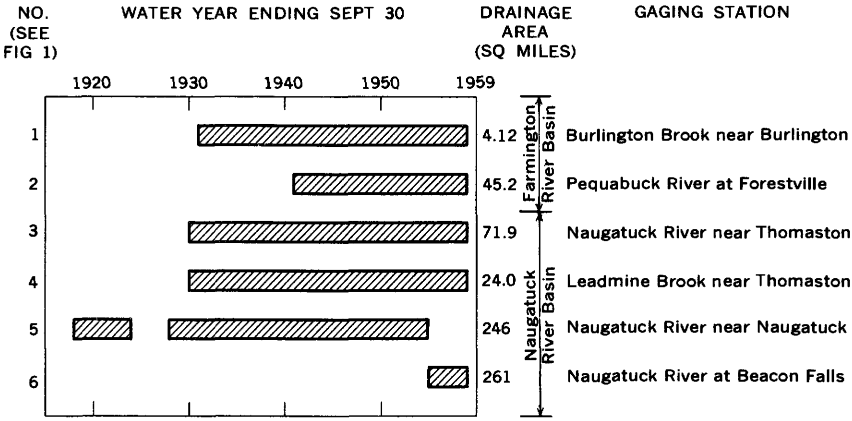

FIGURE 13.—Duration of records at gaging stations in the Waterbury-Bristol area and vicinity.

RECORDS AVAILABLE

Hydrologic data for some streams and aquifers in and adjacent to the Waterbury-Bristol area have been collected for more than 30 years. The Geological Survey in cooperation with the Connecticut Water Resources Commission and the City of New Britain has measured the streamflow at six gaging stations on Naugatuck River, Leadmine Brook, Pequabuck River, and Burlington Brook for the past 28 to 31 years (fig. 13). Fluctuations of ground-water levels in five wells have been recorded since 1944. The chemical quality of water from Naugatuck River, Leadmine Brook, and Pequabuck River has been determined periodically since 1954, and the sulfate content of water from selected wells has been determined periodically since 1944.

Plate 1 shows the general location of each of the six nearby gaging stations. The station on the Pequabuck River is the only one that is within the report area. However, records for the Naugatuck River near Thomaston and Naugatuck (Beacon Falls) are useful in evaluating the characteristics of this river as it flows through Waterbury. Records for Burlington and Leadmine Brooks are typical of small streams in the Farmington and Naugatuck River basins, respectively. Consequently, records for all six gaging sites are analyzed in this report. A summary of discharge data is presented in table 8.

WATERBURY SUBAREA

NAUGATUCK RIVER

The Naugatuck River has a narrow valley 54 miles long and a drainage area of 311 square miles. It enters the Housatonic River at Derby about 15 miles south of the Waterbury-Bristol area (fig. 1).

TABLE 8.—*Summary of streamflow data, Waterbury-Bristol area*

Location on fig. 1	Stream	Gage location	Drainage area (sq mi)	Elevation of gage (ft above msl)	Average flow			Maximum flow during major floods			Minimum daily flow	
					Period of record	Quantity (mgd)	Number of years	Quantity (cfs)	Gage height (feet)	Date	Quantity (mgd)	Date
1	Burlington Brook	Burlington	4.12	714.00	1931-59	5.29	28	1,690	9.22	Aug. 19, 1955	0.3	July 18, 1957.
								676	7.24	Sept. 21, 1938		
								591	6.87	Dec. 31, 1948		
								533	6.58	Mar. 12, 1936		
								505	6.42	Jan. 25, 1938		
2	Pequabuck River	Forestville	45.2	197.72	1941-59	56.3	18	11,700	13.22	Aug. 19, 1955	4.5	Sept. 2, 28, Oct. 26, 1941.
								4,170	7.67	Oct. 16, 1955		
								3,800	7.3	Sept. 21, 1938		
								3,260	6.70	Dec. 31, 1948		
3	Naugatuck River	Thomaston	71.9	389.44	1930-59	93.1	29	41,600	24.0	Aug. 19, 1955	6.1	Sept. 29, 1957.
								10,200	12.03	Dec. 31, 1948		
								9,970	11.89	Sept. 21, 1938		
								8,100	10.30	Oct. 15, 1955		
								6,830	9.57	Jan. 25, 1938		
								6,590	9.37	Mar. 12, 1936		
4	Leadmine Brook	do	24.0	401.23	1930-59	31.1	29	10,400	13.10	Aug. 19, 1955	.05	Aug. 20, 1957.
								6,160	11.17	Sept. 17, 1934		
								6,050	11.14	Sept. 21, 1938		
								5,150	10.63	Dec. 31, 1948		
								4,830	10.43	Mar. 12, 1936		
5	Naugatuck River	Naugatuck	246	155.17	1918-24, 1928-55	307	37	106,000	25.7	Aug. 19, 1955	26	Oct. 5, 12, 1930.
								30,400	13.7	Oct. 16, 1955	26	Sept. 7, 1936.
6	do	Beacon Falls	261	117.28	1956-59			28,500	12.40	Dec. 31, 1948		
								26,000	14	Nov. 1927		
								25,300	12.40	Sept. 21, 1938		
								23,300	11.96	Mar. 12, 1936		

The principal tributaries of the Naugatuck River within the subarea are Hancock and Steel Brooks and Mad River (pl. 1). The main channel and its tributaries are steep, and the beds of the streams are stony in many places. The soil is thin throughout the valley and denuded ledges are common. As a result, runoff is rapid and flood flows are high and of short duration. The river enters the report area a few miles above Waterbury and flows southward across the southwestern part of the area (pl. 1). It flows through the city of Waterbury but is not gaged at this point. However, records have been kept for many years above Thomaston, about 10 miles upstream from the center of Waterbury, , and also below Naugatuck, about 7 miles downstream from Waterbury. The water-supply system for the city of Waterbury originates in Branch Brook, a tributary which enters the Naugatuck River from the west about 5 miles upstream from Waterbury. A small amount of water from Shepaug Reservoir near Woodville is diverted into the basin at Pitch Reservoir on Branch Brook. Most of the water reenters the Naugatuck River above Naugatuck after use by the city of Waterbury.

Records of the discharge for the Naugatuck River near Thomaston, 0.4 mile upstream from the confluence of Leadmine Brook, began in October 1930 (fig. 13). This site was abandoned in October 1959 because of submergence by the pool created by the new Thomaston flood-control dam, and the gage was relocated at Thomaston, 2¼ miles downstream (drainage area, 105 sq mi). Records for the Naugatuck River near Thomaston have been combined with those for Leadmine Brook near Thomaston for this study. These combined records represent flow conditions at the confluence of the two streams just upstream from the Thomaston damsite near the northwest corner of the report area, where the drainage area is 96.4 square miles. Average discharge of the combined flows for the 29-year record (1931–59) is 124 mgd or 192 cfs (cubic feet per second). The minimum daily discharge was 6.5 mgd (10 cfs) on September 29, 1957. A summary of streamflow data for the two sites appears in table 8.

The flow characteristics of the Naugatuck River below its confluence with Leadmine Brook near Thomaston are shown by the flow-duration curve in figure 14, which indicates the precent of time specific daily discharges were equaled or exceeded during the period of record. Additional curves show the maximum and minimum percent of time specific daily discharges were equaled or exceeded in any year. For example, the daily flow for the period of record has been equal to or greater than 24 mgd (37 cfs) for 80 percent of the time, the minimum in a single year having been 56 and the maximum 98.2 percent of the time. If hydrologic conditions remain typical and there is little change in storage or release of water, this flow-duration curve could

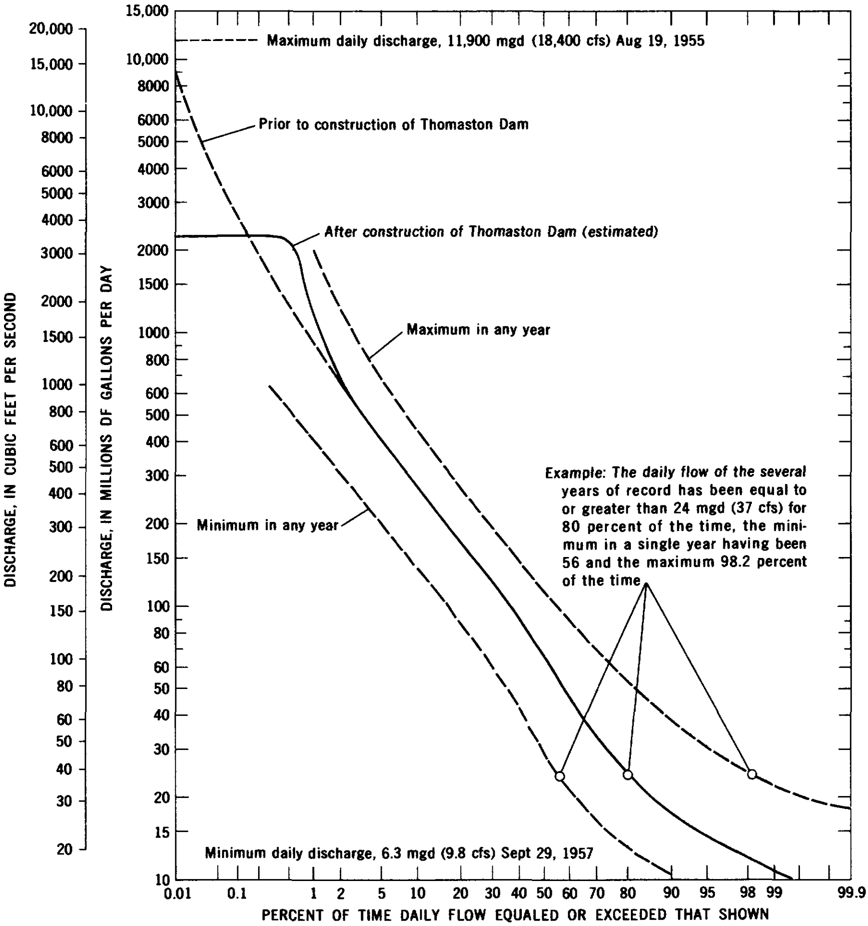

FIGURE 14.—*Duration curve of daily flows, Naugatuck River below Leadmine Brook near Thomaston, 1931–59.*

be used to predict the distribution of future flows of the Naugatuck River at this point. The operation of the new Thomaston flood-control dam, however, will change the shape of this curve considerably through storage and release of flood waters. An estimated flow-duration curve after construction of Thomaston Dam also appears in figure 14. This curve shows that flows of less about 500 mgd (770 cfs) will pass freely through the dam and that flows above this will be regulated in such a way that the maximum channel capacity immediately below the dam of about 2,260 mgd (3,500 cfs) will be utilized when downstream conditions permit. Flows in excess of about 2,260 mgd will occur only rarely.

Flow-duration curves do not show whether the days of deficient flow will be consecutive or how frequently they will occur. To ob-

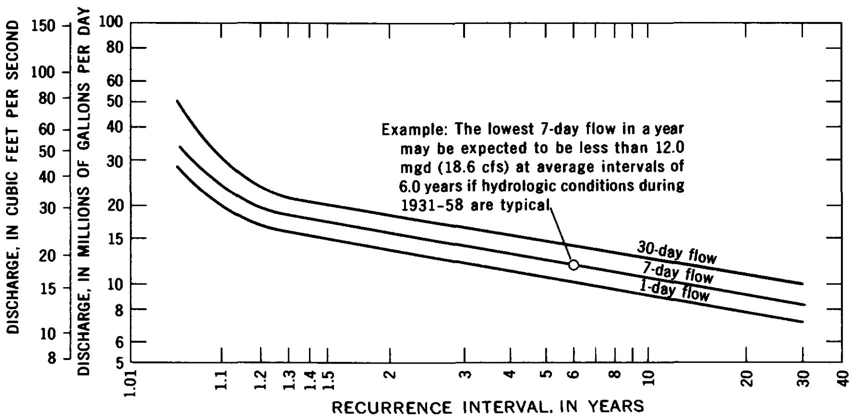

FIGURE 15.—Magnitude and frequency of annual low flows, Naugatuck River below Leadmine Brook near Thomaston, 1931–58.

tain such information, low-flow frequency curves and curves for the maximum period of deficient discharge are necessary. Figure 15 presents curves showing the magnitude and frequency of annual low flows for periods of 1, 7 and 30 consecutive days. These curves indicate the average interval at which specific low flows may be expected to recur as the lowest flow during the year under hydrologic conditions such as existed during the 28-year period April 1931 through March 1959. For example, the lowest 7-day flow in any year may be expected to be less than 12.0 mgd (18.6 cfs) at average intervals of 6.0 years if hydrologic conditions during 1931–58 are typical. The maximum period for which the flow was less than a specific discharge is shown by the curve in figure 16. For example, during a 28-year period in which hydrologic conditions are similar to those in 1931–58, the longest period in which the daily flow was less than 13 mgd (20 cfs) would probably be 23 days.

During dry periods, streamflow is frequently inadequate to meet the minimum requirements of use. However, additional flow may be provided by releasing water from reservoir storage. Such storage is called conservation storage as opposed to flood-control storage such as that at Thomaston Dam. Flood-control storage cannot be used for conservation storage since a full reservoir has little value for flood protection and an empty flood control reservoir needed for flood protection is useless for conservation purposes. The curve in figure 17 shows the storage capacity that would have been required to maintain outflow rates during the period 1931–59 if evaporation and seepage losses are considered to be part of the outflow. For example, to meet a sustained demand of 110 mgd from 1939 to 1959 a storage capacity of 28,000 million gallons would have been required.

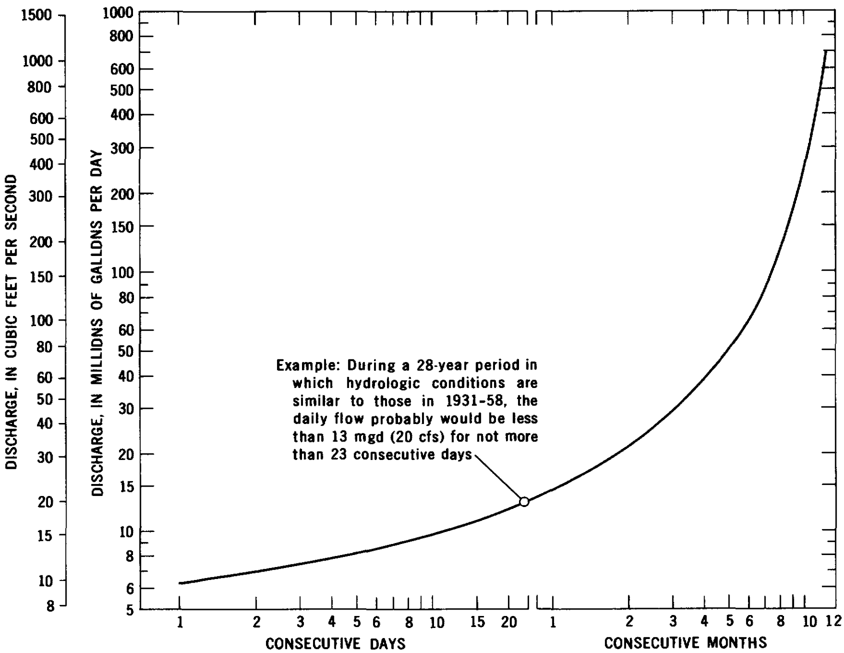

FIGURE 16.—Maximum period of deficient discharge, Naugatuck River below Leadmine Brook near Thomaston, 1931–58.

This required capacity is equivalent to 62 percent of the average annual total flow of the stream.

The low-flow curves and required-storage curve for the Naugatuck River below Leadmine Brook will not be affected by operations at the Thomaston Dam because all flows of less than about 500 mgd will pass freely through the dam.

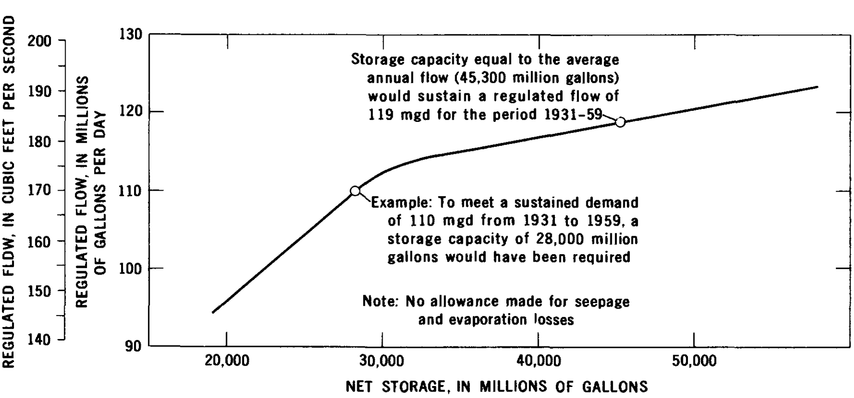

FIGURE 17.—Storage required to maintain flows, Naugatuck River below Leadmine Brook near Thomaston, 1931–59.

Streamflow records were collected on the Naugatuck River near Naugatuck from June 1918 to September 1924 and September 1928 to September 1955 (fig. 13). This gage was destroyed during the flood of August 1955 and was relocated 2 miles downstream at Beacon Falls in October 1955. Records for these sites are considered equivalent, and therefore data is presented in this report as for the Beacon Falls site. Flow characteristics are shown in figure 18, low flow analyses in figures 19 and 20, and storage requirements to maintain flows in figure 21.

The Naugatuck River basin is subject to floods which rise rapidly to high peak runoff rates. The most outstanding flood of record in the basin was that of August 19, 1955, when 52,000 cfs was measured

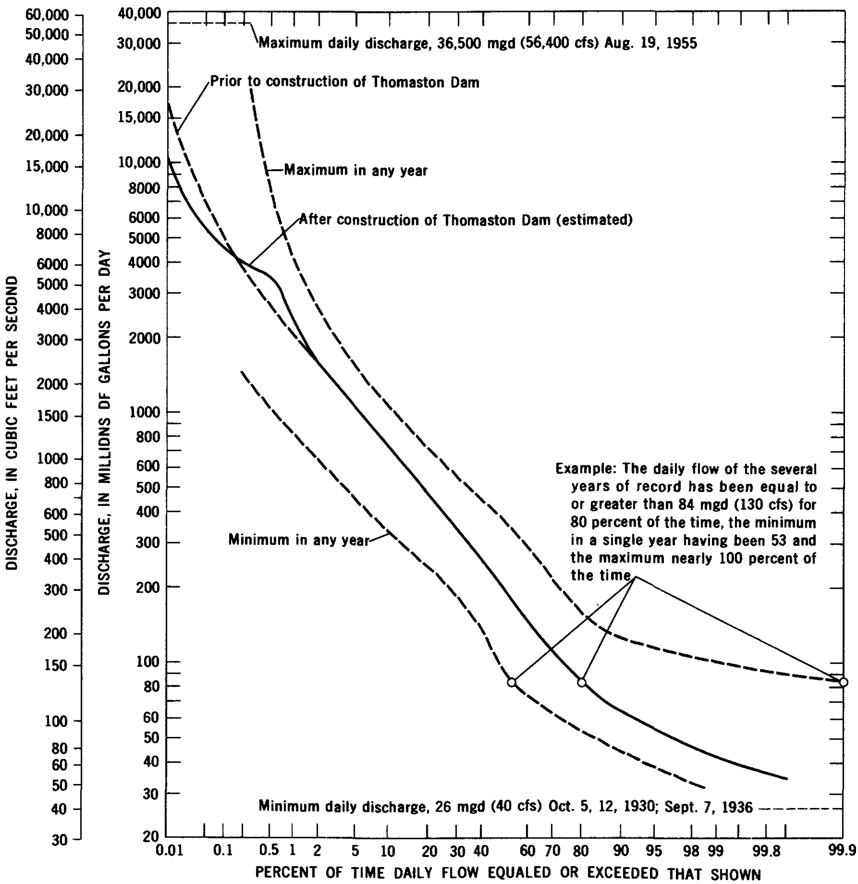

FIGURE 18.—Duration curve of daily flows, Naugatuck River at Beacon Falls, 1929–59.

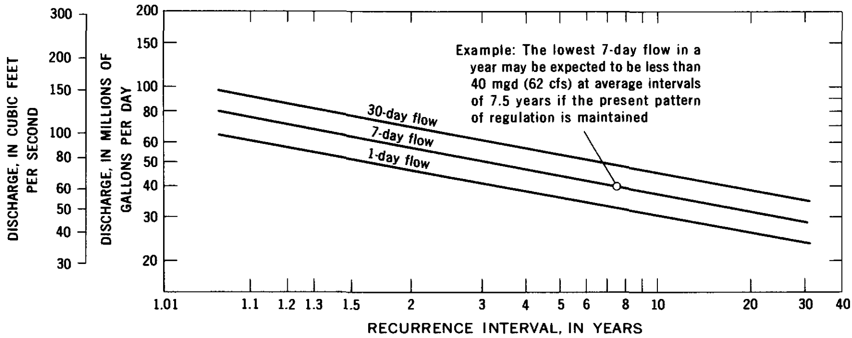

Figure 19.—Magnitude and frequency of annual low flows, Naugatuck River at Beacon Falls, 1929–58.

at the Thomaston damsite and 106,000 cfs at Naugatuck, corresponding to a rise in stage of about 24 and 26 feet above the riverbed, respectively. Other major floods of record are given in table 8. From this table, peak flows for the Thomaston damsite may be determined by adding the peak flows observed at the gages on Naugatuck River near Thomaston and Leadmine Brook near Thomaston because there is little if any difference in the timing of flood peaks on these two streams. Flood-frequency curves for the Thomaston damsite and the site at Beacon Falls are shown in figures 22 and 23.

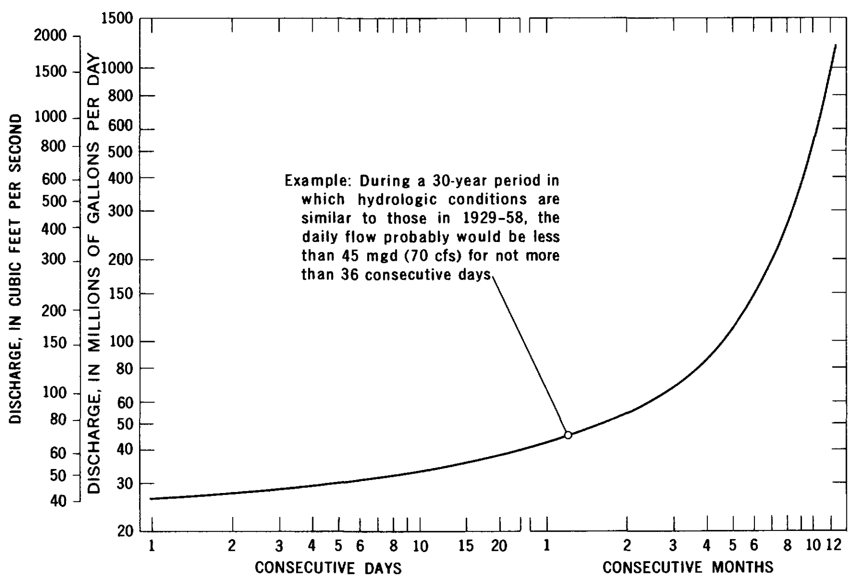

Figure 20.—Maximum period of deficient discharge, Naugatuck River at Beacon Falls, 1929–58.

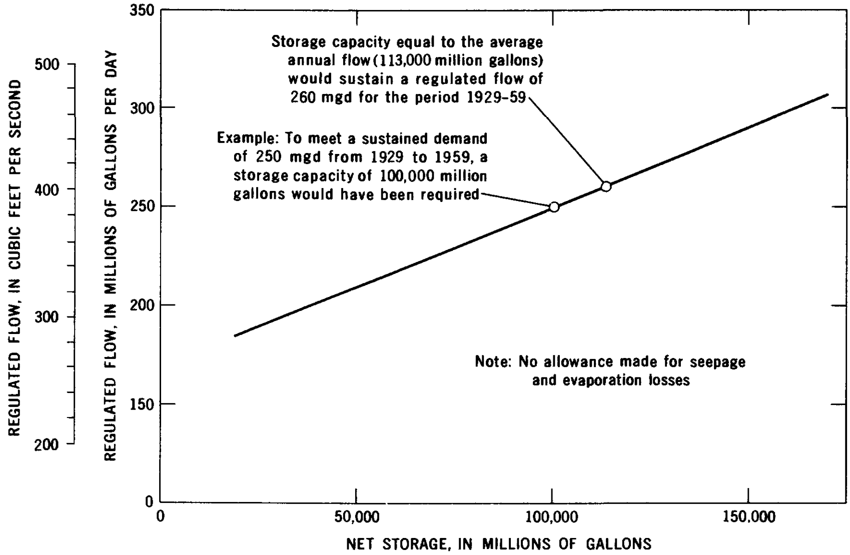

FIGURE 21.—Storage required to maintain flows, Naugatuck River at Beacon Falls, 1929–59.

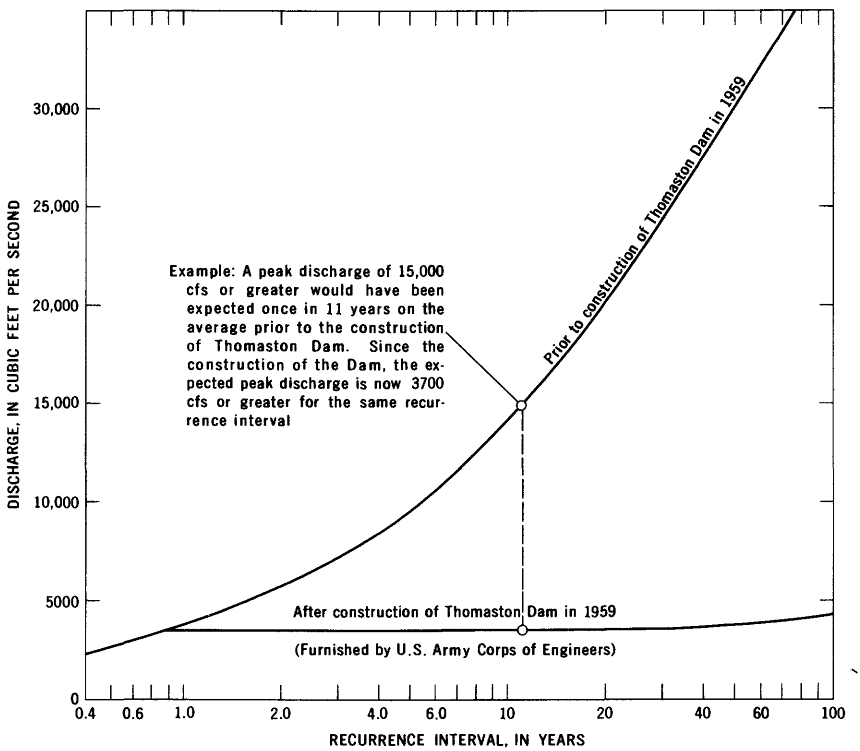

FIGURE 22.—Magnitude and frequency of floods, Naugatuck River below Leadmine Brook near Thomaston, 1929–59.

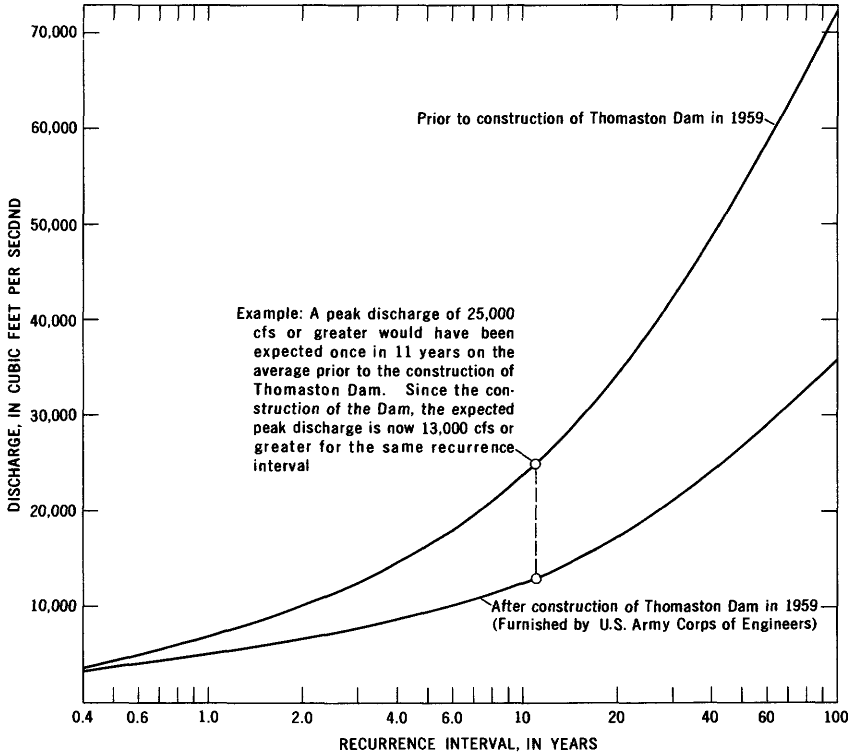

FIGURE 23.—Magnitude and frequency of floods, Naugatuck River at Beacon Falls, 1928–59.

During 1959, construction of the Thomaston flood-control dam and reservoir just below the mouth of Leadmine Brook completely changed the flood characteristics of the river below Thomaston. Figures 22 and 23 include the probable flood-frequency curve after construction of the dam. These curves were furnished by the U.S. Army Corps of Engineers and of necessity are largely theoretical.

The chemical quality of water from the Naugatuck River fluctuates erratically. During the 1958 water year, dissolved solids in composites of water samples collected daily at the stream-gaging site near Thomaston ranged from 46 to 171 ppm, with a time-weighted average of 82 ppm (table 9). Daily fluctuation in solute material based on specific conductance (an approximate measure of dissolved solids) is even more striking (fig. 24). At the gaging station at Beacon Falls, about 12 miles south of Waterbury, the dissolved solids ranged from 60 to 186 ppm.

Near Thomaston abrupt changes in dissolved-solids content in water from the Naugatuck River occurred from day to day during low flow

TABLE 9.—*Summary of chemical data, Naugatuck River near Thomaston, October 1957 to September 1958* [1]

[Chemical constituents, in parts per million]

Constituent	Time-weighted		
	Minimum	Average	Maximum
Silica (SiO_2)	6.3	9.2	17
Iron (Fe)	.09	.37	1.4
Calcium (Ca)	6.4	9.2	15
Magnesium (Mg)	1.8	2.9	4.9
Sodium (Na)	2.7	8.3	25
Potassium (K)	.8	1.9	4.8
Bicarbonate (HCO_3)	0	24	100
Sulfate (SO_4)	10	20	80
Chloride (Cl)	1.2	7.1	13
Fluoride (F)	.0	.2	.4
Nitrate (NO_3)	.6	7.9	29
Dissolved solids	46	82	171
Hardness as ($CaCO_3$)	22	38	80
Specific conductance micromhos at 25°C	68	129	357
pH	4.5	----------	[2] 9.1
Color	3	9	33
Oxygen consumed:			
Filtered	2	----------	5
Unfiltered	5	----------	14

[1] Based on analyses of composite samples (U.S. Geol. Survey, 1962).
[2] Includes 35 ppm carbonate (CO_3) and 1 ppm hydroxide (OH).

(usually less than 10 cfs). The calcium concentration doubled on some days; magnesium and potassium changed only slightly; sodium concentrations increased approximately four to six times. Iron concentration in the water (fig. 25) was highest during periods of low flow (indicated by hydrograph in fig. 24); the maximum iron concentration in a single daily water sample was 1.8 ppm.

Bicarbonate alkalinity ranged from 0 to 100 ppm in composites of water samples from the Naugatuck River near Thomaston. The pH ranged from 4.5 to 9.1; however, it usually fluctuated between 6.0 and 7.0. The zero concentrations for bicarbonate alkalinity and the pH values of 4.5 and 9.1 were unusual.

The variation in the chemical composition of the Naugatuck River was also reflected in the hardness of the water. At the gaging station near Thomaston, the hardness of the water ranged from 22 to 80 ppm, and the time-weighted average was 38 ppm. Figure 26 shows the monthly average hardness of the water during 1957–58. The maximum sulfate concentration in composite samples collected near Thomaston was 80 ppm, but 93 ppm was found in a sample collected at Beacon Falls.

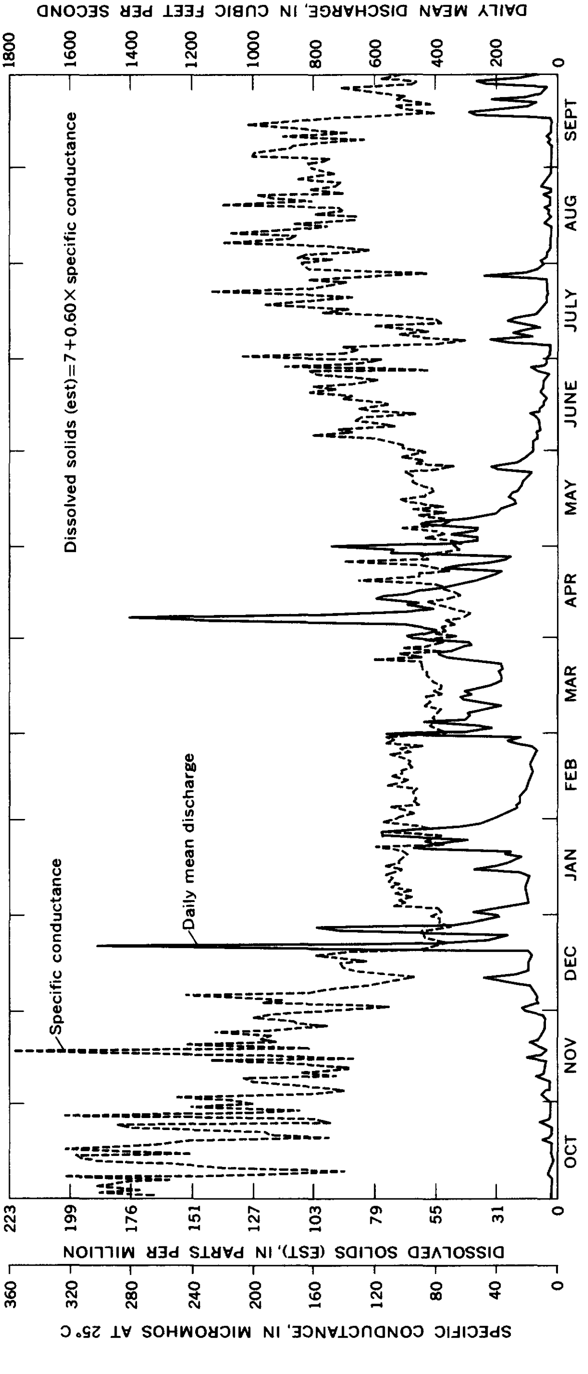

FIGURE 24.—Specific conductance and daily mean discharge, Naugatuck River near Thomaston, 1957–58.

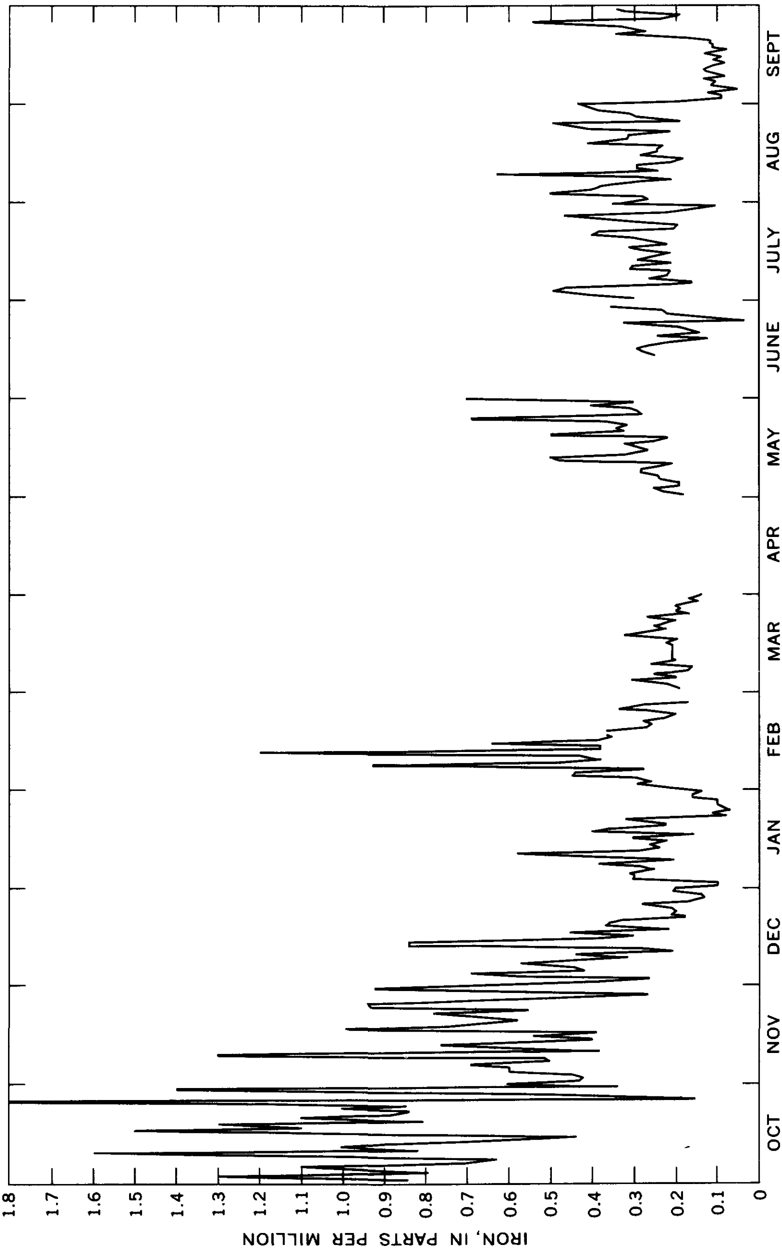

FIGURE 25.—Daily iron concentrations in Naugatuck River near Thomaston, 1958 water year.

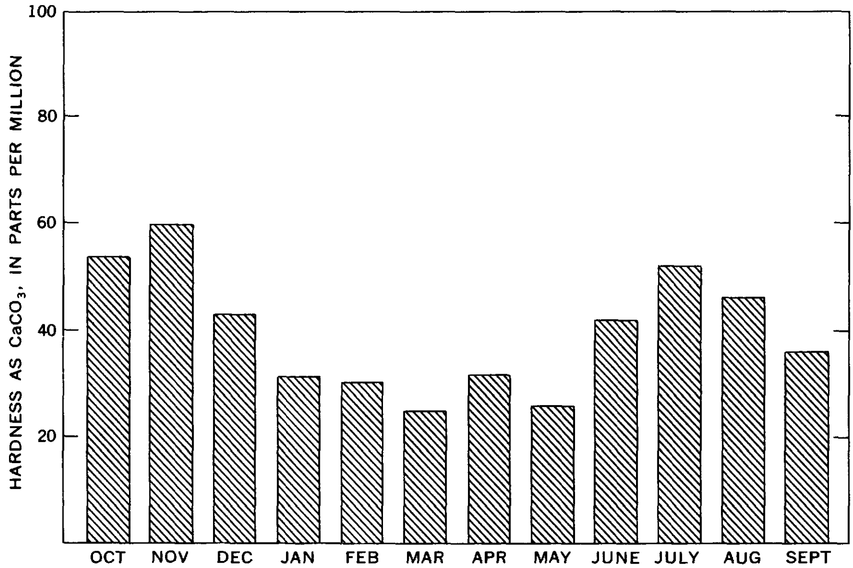

FIGURE 26.—Monthly average hardness as $CaCO_3$ in Naugatuck River near Thomaston, 1957–58.

The chemical quality of water from the Naugatuck River improved when streamflow increased. Dilution had a modifying effect on the concentrations of dissolved solids, as well as on the individual constituents (fig. 24).

Temperature of the Naugatuck River followed a seasonal pattern, decreasing in the fall, hovering near freezing during the winter months and gradually rising in the spring. The highest temperature of the Naugatuck River at Thomaston recorded during 1957–58 was 83°F. The water temperature was greater than 65° about 30 percent of the time (fig. 27).

The development of brass- and copper-fabricating plants has been an economic gain to the Waterbury subarea, but the disposal of industrial wastes from these plants and others upstream from Waterbury has created a major pollution problem in the Naugatuck River. According to a report issued by the New England Interstate Water Pollution Control Commission (1951), wastes discharged from brass and copper plants create the greatest pollution problem because they contain such substances as free acids, alkalies, cyanides, chromium, copper, and zinc. A survey made in conjunction with a study of the resources of the New England-New York Region by the New England-New York Inter-agency Committee (1956) showed that below Waterbury, most of the Naugatuck River was not suitable for any use, or at best was suitable only for transportation of sewage and industrial

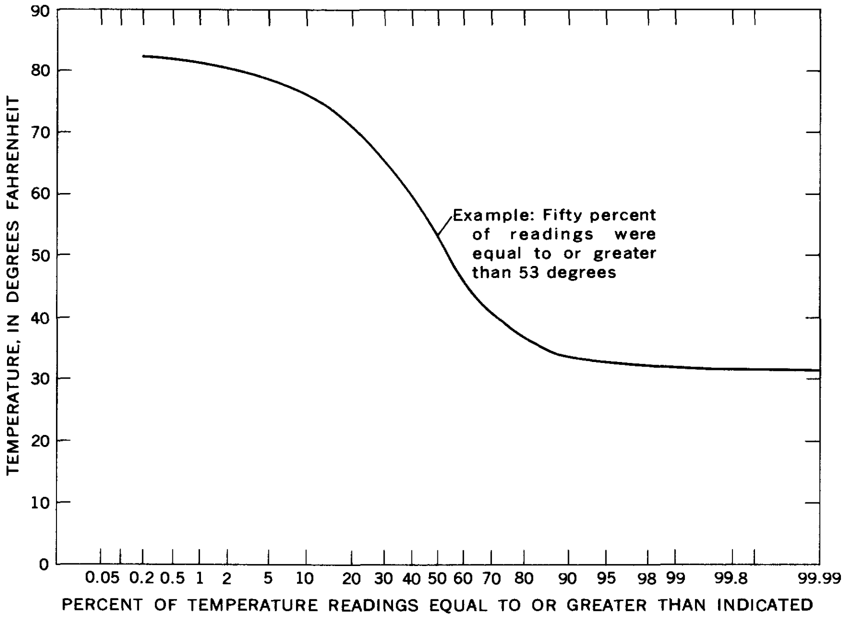

FIGURE 27.—Frequency distribution of water temperatures, Naugatuck River near Thomaston, 1957–58.

wastes without nuisance, and for power, navigation, and some other industrial uses. This condition was present during periods of low flow. During high flow, dilution reduces the concentrations of waste material.

The data in table 9 do not show the extent and kind of pollution in the Naugatuck River. However, the pH values of 4.5 and 9.1 indicate unusual conditions that are attributed to pollution. Iron concentrations as high at 1.4 ppm were determined in some daily samples and are also attributed to industrial pollution.

LEADMINE BROOK

Leadmine Brook enters the Naugatuck River from the east, 2 miles upstream from Thomaston (fig. 1). It is 10.6 miles long and has a drainage area of 24.2 square miles. Although not in the area covered by this report, it is close by and is typical of small streams on the east side of the Naugatuck River basin. It is a mountain stream with steep slopes, rock gorges, and rapid runoff, and its flood peaks are high and of short duration. During dry weather, however, the flow approaches zero.

Records of the flow of Leadmine Brook at a site 0.4 mile upstream from its mouth began in September 1930 (fig. 13). In November 1959 this site was abandoned because it was within the pool of the new Thomaston flood-control dam. The gaging station was relocated at a new site at Roraback Lodge, 2.4 miles upstream (drainage area, 18.9 sq mi) in February 1959. A summary of streamflow data at the site near Thomaston appears in table 8.

The flow characteristics of Leadmine Brook are shown by the flow-duration curve in figure 28. Also shown, for comparison, are

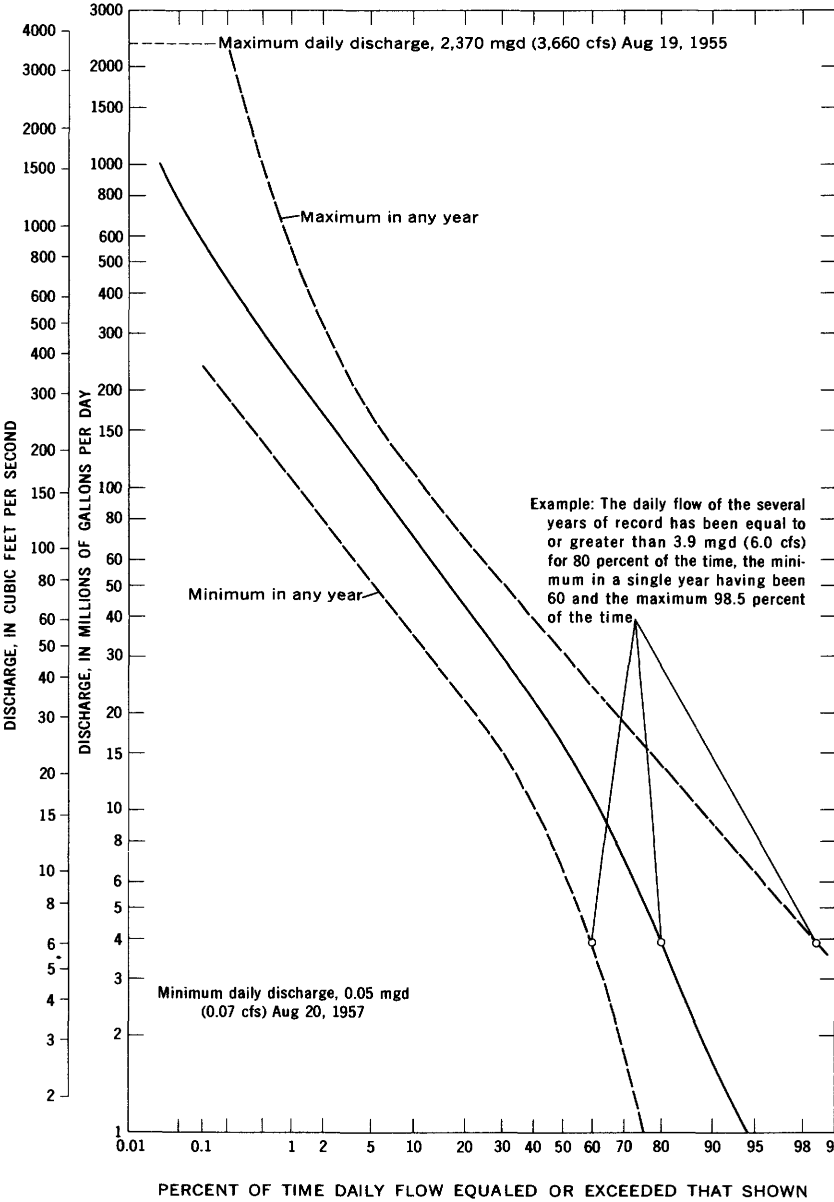

FIGURE 28.—Duration curve of daily flows, Leadmine Brook near Thomaston, 1931–59.

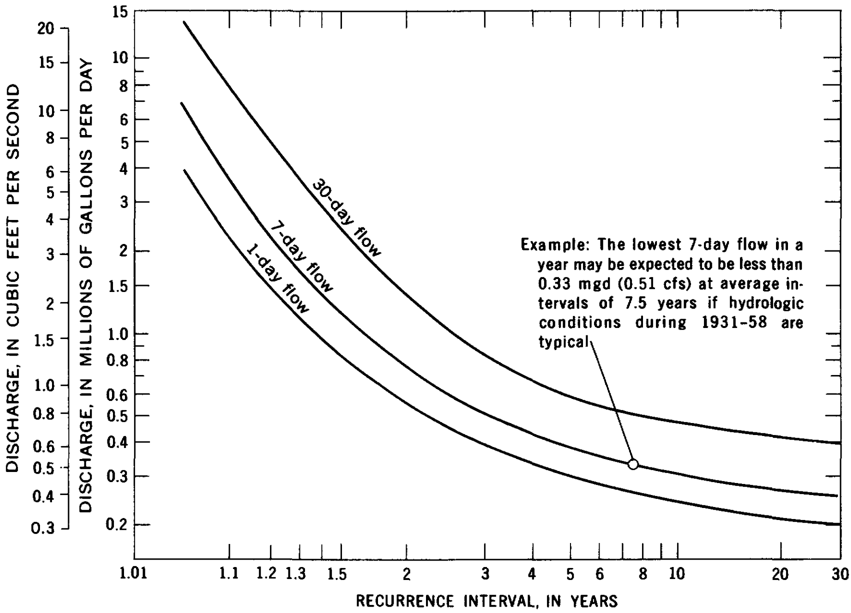

FIGURE 29.—Magnitude and frequency of annual low flows, Leadmine Brook near Thomaston, 1931–58.

curves for both maximum and minimum percent of time that specific daily discharges were equaled or exceeded in any year.

Low-flow frequency curves, figure 29, show the average flow during periods of 1, 7, and 30 consecutive days. A curve showing the maximum period for which the flow was less than a specified discharge is shown in figure 30. Storage required to maintain flow of Leadmine Brook is shown in figure 31.

A detailed description of figures 28–31 is given earlier in this report for similar figures 14–17 for the Naugatuck River. Flow data from figures 28–31 may be adapted for use of points on other similar streams east of the Naugatuck River within the report area, by adjusting it in proportion to the drainage area of the respective basins.

Leadmine Brook is subject to floods of high runoff. Perhaps the highest that ever occurred was that of August 19, 1955. The water surface at the gage site reached an altitude of 414.3 feet above mean sea level, 12 feet above the bed of the brook, and the flow was 10,400 cfs. Table 8 notes other major floods of record. A flood-frequency curve showing the average interval in years between floods that equal or exceed a given discharge is shown in figure 32.

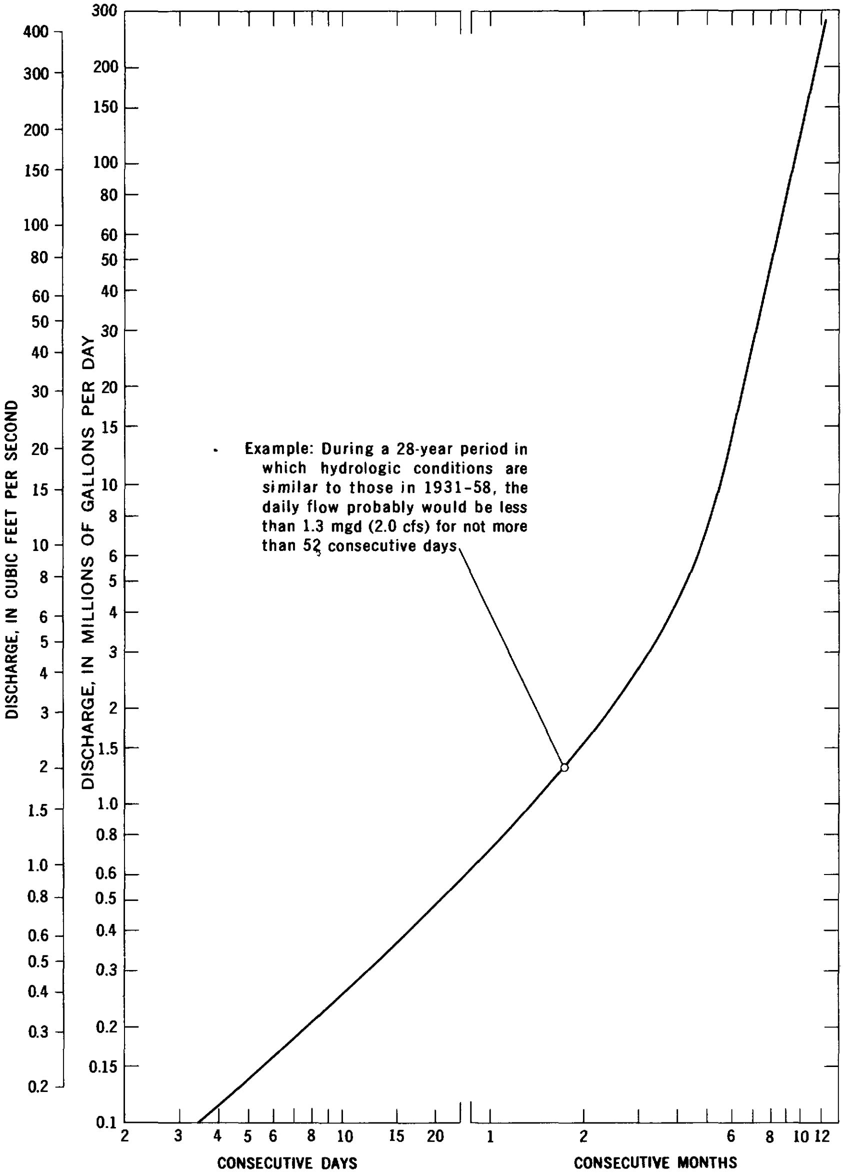

FIGURE 30.—Maximum period of deficient discharge, Leadmine Brook near Thomaston, 1931–58.

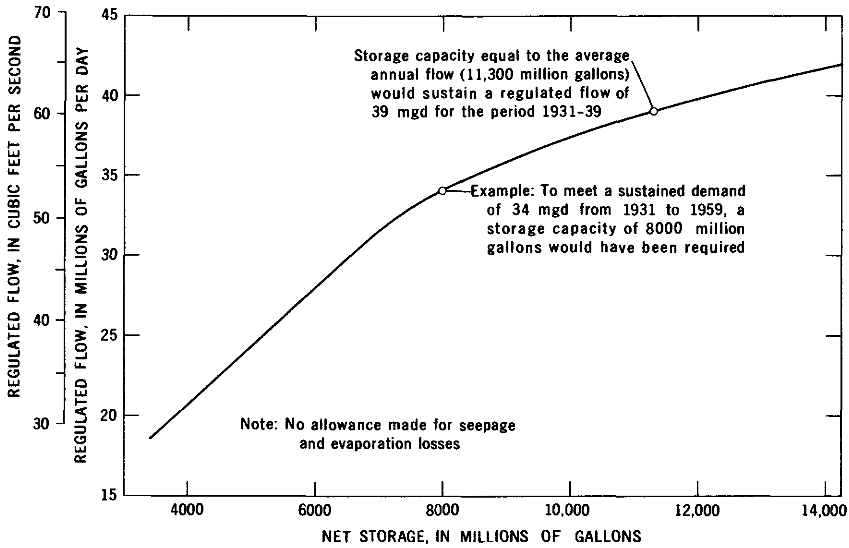

Figure 31.—Storage required to maintain flows, Leadmine Brook near Thomaston, 1931–59.

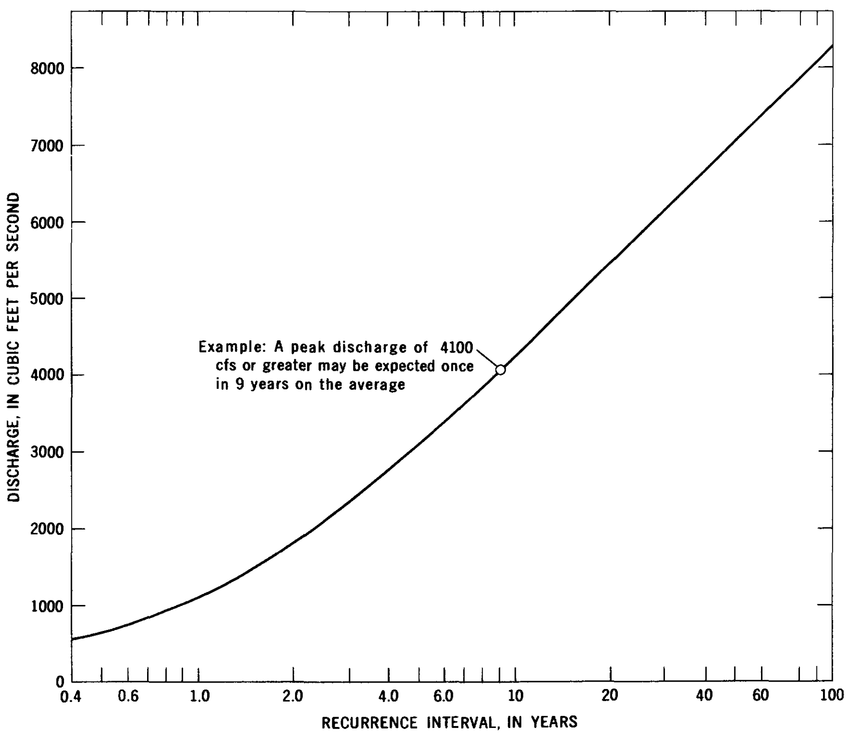

Figure 32.—Magnitude and frequency of floods, Leadmine Brook near Thomaston, 1931–59.

SAND AND GRAVEL AQUIFERS

Moderate supplies of ground water can be obtained from deposits of sand and gravel in the Waterbury subarea. Several aquifers (water-bearing formations), defined on the basis of local geology, are potential sources of ground water. These include deposits of sand and gravel along the Naugatuck River and near the Mad River, and several other small deposits in upland valleys. Areas underlain by these deposits are shown on plate 1.

A major sand and gravel aquifer occurs along the Naugatuck River in Waterbury. The river is bordered by sand and gravel everywhere except at the north boundary of the town, where it is enclosed in a bedrock gorge. The band of sand and gravel averages 0.2 to 0.4 mile in width, but widens to about a mile in downtown Waterbury and also extends up the valleys of Hancock and Steel Brooks (pl. 1). The deposits probably do not exceed 150 feet in thickness; the maximum known thickness is 129 feet near the junction of Steel Brook with the Naugatuck River. The thickness of the unconsolidated deposits at any point may be estimated by substracting the altitude of the bedrock surface from the altitude of the land surface, both of which are shown by means of contours on plate 1.

The beds of sand and gravel were laid down by south-flowing glacial melt-water streams. Most of the beds were deposited in immediate contact with the melting ice, although some in the center of the valley may have been deposited after the ice had retreated farther north. The oldest deposits occur only along the margins of the lowland and are not continuous; their maximum altitude is about 370 feet near Waterville, 350 feet in the business district of Waterbury, and 330 feet near Platts Mills. They are in large part above the water table.

Excavations in sand and gravel deposits along the Naugatuck River reveal relatively coarse-grained material; medium sand to gravel predominates over finer sediment, and beds of pebbles, cobbles, and boulders are fairly common. Coarse material appears to be as prevalent near the bases of the 10- to 40-foot exposures as it is near the top. However, the deposits are highly variable both vertically and laterally; adjacent beds may vary widely in average grain size. Many beds are lens-shaped, and others are warped. Also, many of the coarse-grained beds are very poorly sorted. Poorly sorted materials, so called because they contain a wide variety of coarse and fine sizes, transmit water much more slowly than materials in which the grains are more nearly the same size.

Large boulders are sprinkled here and there through both coarse- and fine-grained strata. These features reflect rapid deposition and collapse adjacent to melting ice.

Records of wells and test borings along the Naugatuck River valley indicate that deposits below the surface are generally similar to those exposed. The records indicate that medium and coarse sand, and commonly gravel, are present at most sites and at various depths but that poor sorting is common. Marked vertical and lateral variability in grain size and sorting appears to be the rule.

At least 40 major wells have tapped the sand and gravel deposits along the Naugatuck valley in Waterbury, although these are not all still in use. Most of these wells yield 300 gpm (gallons per minute) or less. The greatest reported yield is 870 gpm (well Wb16, table 7); the smallest is 30 gpm. Most of the smaller reported yields are from wells where demand for water is small and the reported yield apparently does not represent the maximum capacity of the well. Therefore, almost all these wells probably yield at least 50 gpm. The yield obtained per foot of drawdown (specific capacity) ranges from 2 to 35 gpm per ft on the basis of a few determinations. Depths of wells range from 20 to 100 feet, with the median depth being about 53 feet. The proportion of large yields is about equal among wells above and below the median depth. Several wells are reported to have decreased in yield after several months or years of use owing to reduced permeability in the vicinity of the screen. The reduction in permeability was caused by chemical encrustation or plugging by fine sand and silt. Where chemical treatment and (or) redevelopment were tried, the wells usually were restored to approximately their original yields.

This summarized information indicates that well yields of 50 gpm or more can be obtained at most sites in the aquifer along the Naugatuck valley, except where the saturated part of the sand and gravel is thin. Test drilling is advisable to select the best sites and depths in these variable deposits, particularly if large yields are desired. Careful, perhaps prolonged, development is necessary to obtain maximum yields, and periodic redevelopment and treatment may be required to maintain yields. With test drilling at several sites and thorough well development, it should be possible to obtain yields of at least 150 gpm, and perhaps as much as 1,000 gpm.

In the Naugatuck River valley, as elsewhere in the Waterbury-Bristol area, ground water under natural conditions flows gradually toward the streams, eventually discharging into them by seepage. In the relatively permeable sand and gravel of the Naugatuck valley, the water table is no more than a few feet above the altitude of the streams, so that water levels in wells are 10 to 25 feet below the surface of the flood plain and low terraces. Ground water in the sand and gravel is derived principally from locally infiltrating precipitation and from lateral underground flow from the bedrock and surficial deposits that form the valley walls. Heavy pumping of ground water near a stream may, however, lower the water table enough to induce recharge from the stream, and if pumping is prolonged this water will be drawn to the well. Several wells in the Naugatuck valley aquifer clearly derive part of their supply in this manner, as shown by the high sulfate content of the water. (See Wb 10a, 11, and 339, tables 7 and 10.) The major part of the water pumped from the aquifer, however, is ground water in transit toward the river and represents reduced natural discharge rather than induced recharge. The low sulfate content of water from several wells, some of them very close to the Naugatuck River, indicates that very little if any water from the river has been drawn into these wells. (See Wb 12, 334, and 335, tables 7 and 10.) Induced recharge depends on such factors as rate and continuity of withdrawal, distance from the stream, well depth, and season of the year.

The sand and gravel aquifer in the Naugatuck River valley is capable of yielding considerably more water than the amount pumped in 1959. Only in a few localities where several wells have been installed 100 to 200 feet apart does interference between wells appear to have been significant. It should be kept in mind, however, that large, prolonged withdrawal, especially close to the Naugatuck River, could result in increased infiltration of highly mineralized river water into the aquifer.

A potentially important sand and gravel aquifer occurs in the vicinity of the Mad River in eastern Waterbury and southwestern Wolcott. It merges with the Naugatuck valley aquifer near the intersection of Hamilton and East Main Streets in Waterbury; from there it extends eastward and northward to the vicinity of Scovill Reservoir in Wolcott. The sand and gravel body exceeds 0.5 mile in width in most places. Near Meriden Road (U.S. Highway 6A), several till-covered bedrock hills protrude through it, and near its junction with the Naugatuck valley aquifer it narrows to only 0.15 mile. The maximum known thickness of sand and gravel is 52 feet, as reported in test borings for the Waterbury Expressway. The saturated thickness is probably everywhere less than 100 feet, although beneath a few high sand hills total thickness may exceed this figure.

The deposits in the vicinity of the Mad River, like most other sand and gravel deposits in the Waterbury subarea, appear to be relatively coarse grained but commonly poorly sorted. Test borings penetrating these deposits were made at several sites along the new Waterbury Expressway. Well over half the units penetrated at each site are described as chiefly medium sand, coarse sand, or gravel, with at least a little gravel reported at more than half the sites. Some of this material is doubtless poorly sorted, but the general coarseness suggests that much of it may be rather permeable. Deposits penetrated by wells Wb 344 to 346 were described by the driller as chiefly "gravel with some clay" and "hardpan gravel," a description suggesting material that was not well sorted.

Only a few wells obtain water from the sand and gravel deposits along the Mad River lowland. Four such wells are described in table 7, from which the following data are summarized:

	Wells			
	Wb 3a	Wb 344	Wb 345	Wb 346
Depth ft	35	35	40	44
Yield gpm	225	115	150	250
Specific capacity gpm per foot of drawdown	12	5	5	12

In addition, near where Silver Street crosses the Mad River about 2 miles above its junction with the Naugatuck River, four wells were drilled and tested at 200 gpm each with specific capacities ranging from 7 to 10 gpm per ft, but the yields reportedly declined after a few days of use. These wells may have been spaced too closely or may have needed more development. In general, yields of 50 to perhaps 400 gpm could probably be obtained by individual wells at most places within this aquifer. There are, however, a few unfavorable localities. The deposits within and for 400 feet north of Calvary Cemetery on East Main Street and those northwest of Meriden Road in the Mill Plain area are probably essentially above the water table. Those upstream from where the Mad River flows through a narrow gap 2,500 feet northeast of the Wolcott city line are thin saturated thicknesses probably less than 20 feet. Shallow wells in this locality close to the shores of Scovill Reservoir or the Mad River probably could obtain large supplies by induced infiltration from the surface-water bodies, but elsewhere large-capacity wells are unlikely.

Depth to water within the sand and gravel deposits of the Mad River valley reflects the altitude of the land surface above the nearest stream. The water table is less than 10 feet below the flat valley-bottom land, but it may be as deep as 60 feet below some higher sand hills.

The possible yield of this aquifer clearly far exceeds the relatively small amount of ground water currently being withdrawn, and additional development is possible. Because poor sorting and thin saturated deposits are common, groups of wells may be needed to provide large supplies in some localities. Wells could be placed adjacent to the Mad River or the ponds along it so that induced recharge would help to sustain their yields. The water thus obtained should not be excessively high in dissolved solids.

Several small areas of sand and gravel occur along upland valleys in the developed section of Waterbury (pl. 1). These deposits are relatively poor aquifers.

A body of sand containing less gravel than many in the Waterbury subarea lies along North Main Street and Chase Avenue at and west of Lakewood in the northern part of Waterbury. The saturated section is probably thin, but small supplies might be obtained from shallow wells.

A flat area about 0.2 mile in width along North Main Street southeast of Webster School in central Waterbury may be underlain by sand and gravel. A well near the southeast edge of the area reportedly penetrated 20 feet of sand above bedrock; another near the northwest edge met rock at 25 feet. A somewhat greater thickness is possible near the center of the valley. The deposits may be largely saturated near the pond at the north end of the area, whereas the south end overlooks a steep slope and is probably well drained. Small supplies might be obtained near the center and north ends. Drainage from large masses of trash and cinder fill just to the north along Great Brook might influence the chemical quality of ground water in the area.

Deposits of sand that contain some gravel are as much as 50 feet thick in knolls and terraces around and north of East Mountain reservoir in the southeastern part of Waterbury, but these deposits are mostly above the water table. The thickness of saturated sand and gravel is not known. Wells yielding moderate supplies could probably be constructed in the deposits east and west of the reservoir, but the total water supply thus obtained would be little or no greater than that already available from the reservoir.

A small body of sand and gravel occurs south of Pearl Lake Road in the southern part of Waterbury. The thickness of the deposits in this area is not known. The deposits may be thin and largely unsaturated in the western half of the area. Along the small valley in the eastern half, however, the sand and gravel may extend far enough below the water table to yield small to possibly moderate amounts of water to wells. These deposits are continuous to the north. A small body of sand and gravel occurs around and north of Pritchards Pond. The north and west boundaries of the latter area of sand and gravel are uncertain; its extent may be somewhat greater or smaller than shown on plate 1. Although the deposits are probably only 20 to 30 feet thick, small to possibly moderate yields might be obtained from shallow wells, particularly near Pritchards Pond. Three wells drilled for the Somers Brass Co. about 2,000 feet northwest of Pritchards Pond are reported to have been screened in surficial deposits as well as drilled into rock; the screened zone may be part of this aquifer or a local permeable zone in the underlying ground moraine. Little water is obtained from the surficial material, however. The three wells reportedly yield only 14 to 20 gpm, about the same as two similar wells nearby that are completed only in crystalline rock.

Analyses data of water samples from 11 wells in the Waterbury subarea are given in table 10. All the wells sampled except Wb 3a penetrated the sand and gravel aquifer along the Naugatuck River (pl. 1). Records of the wells are given in table 7. The analyses data indicate that these sources have a wide range in chemical quality. The dissolved solids ranged from 80 to 373 ppm. Hardness of the water ranged from 31 to 196 ppm. These ranges are not necessarily extremes from ground waters in the Waterbury subarea but are representative.

Generally the chemical composition of water from sand and gravel aquifers along the Naugatuck and Mad Rivers consists principally of salts of calcium, bicarbonate, and sulfate. Other constituents, such as magnesium and sodium, are present in lesser concentrations. In water from several wells (Wb 11, 16, 339), manganese content is very high; the maximum concentration determined was 5.6 ppm.

Water from most wells close to the Naugatuck River contains more sulfate than that from wells some distance away. For example, well Wb 17,800 feet from the river, has a sulfate content of 56 ppm, while well Wb 339, only 75 feet from the river, has a sulfate content of 140 ppm. Well Wb 12, which is 1,300 feet from the river, has a sulfate content of only 15 ppm. Other controlling factors besides distance are rate and duration of pumping and recharge to the aquifer other than by infiltration from the river.

Chemical analysis data in table 11 show changes in sulfate content for well Wb 10a during the period 1944–59. The well is about 250 feet from the river and is in a sand and gravel aquifer that contacts the river. Part of the water is obtained by induced infiltration. Variations in sulfate content are attributed to changes in the amount of infiltrated water drawn to the well and variations in the chemical quality of the river.

TABLE 10.—*Chemical analyses, in parts per million, of water from wells in the Waterbury subarea*

Well	Date of collection	Water temperature (° F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color
Wb3a	May 13, 1954		14	0.01	0.02	23	5.6	12	2.5	48	44	10	0.0	16	151	80	41	229	6.6	5
10a	April 28, 1954		15	.05	.01	37	12	17	3.4	39	96	18	.0	33	275	142	110	382	6.4	5
11 [1]	do		15	.06	5.6	52	16	33	4.8	130	107	41	.0	18	373	196	89	565	6.8	3
12	May 13, 1954	53	9.4	.03	.02	9.5	1.8	6.3	1.0	26	15	4.5	.0	6.5	80	31	10	103	6.6	4
16	do	59	14	.01	3.6	18	4.3	8.0	2.7	8.2	79	7.1	.2	.1	146	63	56	204	5.4	5
17	May, 1954		21	.02	1.5	16	3.8	10	2.7	19	56	8.0	.0	6.8	151	56	40	194	6.1	5
334/335 [2]	April 28, 1954	52	7.5	.05	.02	12	2.4	6.3	1.3	28	21	6.2	.0	3.5	90	40	17	122	6.5	5
339	April 29, 1954	52	16	.12	4.1	38	12	29	3.7	71	140	15	.2	4.0	300	144	86	452	6.4	5

[1] Composite sample from 3 wells.
[2] Composite sample from 2 wells.

TABLE 11.—*Sulfate, in parts per million, in water from well Wb 10a, Waterbury, 1944–59*

[Numbers in parentheses refer to the day of the month when sample was collected]

Year	January	February	March	April	May	June	July	August	September	October	November	December
1944					113 (24)	139 (6)	111 (25)	123 (29)		117 (13)	108 (10)	
1944						95 (20)						
1945	112 (3)	85 (19)	83 (5)		71 (5)	67 (4)	103 (26)		108 (26)		110 (28)	
1945		98 (29)										
1946					101 (5)	104 (6)	124 (31)			117 (1)		112 (2)
1947	111 (29)		97 (28)		115 (20)		124 (31)		147 (30)			151 (2)
1948	146 (27)			102 (28)				156 (27)		162 (27)		155 (27)
1949			180 (14)			220 (3)	234 (26)		189 (26)		210 (26)	
1950		86 (28)		126 (27)				183 (30)			171 (6)	
1951		153 (27)			153 (31)						119 (30)	
1952		127 (28)									127 (28)	
1953	162 (28)			153 (1)	158 (29)		144 (29)			162 (1)		
1954	189 (28)			130 (28)			104 (1)		112 (30)			90 (30)
1955			158 (30)									125 (29)
1956			117 (30)				122 (30)		108 (26)			117 (31)
1957			108 (30)									108 (30)
1958			99 (31)			90 (27)			89 (29)			122 (29)
1959			110 (30)		126 (28)					117 (29)		

OTHER SOURCES OF GROUND WATER

Supplies of water adequate for the needs of individual homes and small commercial establishments can be obtained from crystalline bedrock in the Waterbury subarea. The yields of wells tapping rocks are usually inadequate for larger commercial, industrial, and municipal needs. Other small but less reliable supplies are obtained from ground moraine.

Ground moraine is an unconsolidated glacial deposit of variable thickness which mantles the bedrock throughout the Waterbury subarea and which is interrupted locally by bedrock outcrops. It constitutes the surface material on most hills, as shown in plate 1, and commonly underlies the glacial sand and gravel deposits in most valleys. Its water-yielding properties are discussed in the section of this report on the "Rural subarea." In general, it is a poor aquifer in which only large-diameter dug wells yielding less than 5 gpm have been constructed.

The bedrock units in the Waterbury subarea are referred to as crystalline rocks. The water-yielding properties of crystalline rocks are described in the section of this report on the "Rural subarea." In general, most wells provide only small supplies. Of 30 wells drilled in crystalline bedrock for industrial and commercial uses in the Waterbury subarea, only 6 (20 percent) were reported to yield 50 gpm or more. A few reportedly yielded only 4 or 5 gpm, whereas the most productive well (Wb 53) was pumped at 150 gpm. Most of the wells are in the business district of Waterbury and along the Naugatuck River.

BRISTOL SUBAREA

PEQUABUCK RIVER

The Pequabuck River drains the entire Bristol subarea and flows east to Plainville, where it turns abruptly northeast and enters the Farmington River near Farmington about 6 miles northeast of Bristol. It is 19.0 miles long and drains an area of 58.4 square miles. It is a stream having steep slopes and rapid runoff. Its headwater tributaries are controlled by many reservoirs.

The Poland River, a large tributary, is the primary source of water supply for Bristol. The system consists of numerous small reservoirs on the main stream and its tributaries.

New Britain obtains part of its water supply from Whigville Reservoir on Copper Mine Brook, another tributary of the Pequabuck River. Additional water is pumped from wells adjacent to the brook at White Bridge pumping station. Water used by New Britain is lost to the basin.

The flow of Pequabuck River has been gaged at Forestville since July 1941 (fig. 13). A summary of streamflow data is shown in table 8.

The flow characteristics of the Pequabuck River are shown by the flow-duration curve for the period of record (fig. 33). This curve shows the percentage of time during which any specific daily discharge was equaled or exceeded. For comparison, curves for both maximum and minimum percent of time that specific flows were equaled or exceeded in any year of the period of record are also shown.

Low-flow frequency curves, showing the average interval at which specific low flows may be expected to recur in the Pequabuck River under hydrologic conditions such as those during the period 1942–58,

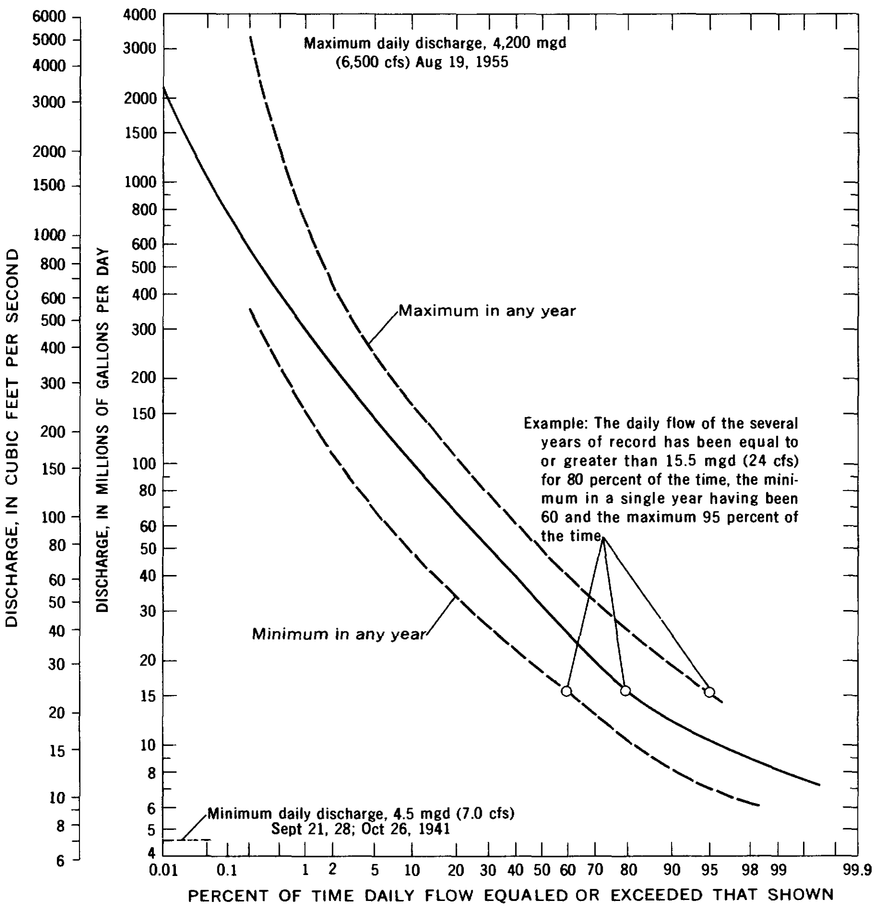

FIGURE 33.—Duration curve of daily flows, Pequabuck River at Forestville, 1942–59.

are shown in figure 34 for average flows during periods of 1, 7, and 30 consecutive days.

Figure 35 shows the maximum period during which the flow at Forestville was less than a specified discharge. Figure 36 shows the additional net-storage capacity that would have been required to maintain specific outflow rates, disregarding evaporation, leakage, and dead storage.

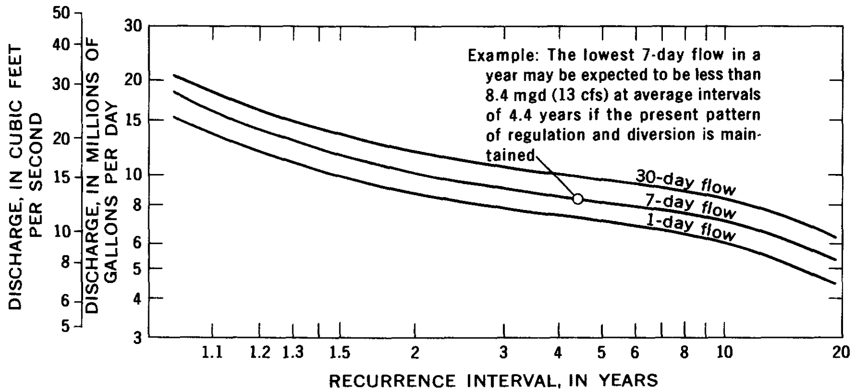

FIGURE 34.—Magnitude and frequency of annual low flows, Pequabuck River at Forestville, 1942–58.

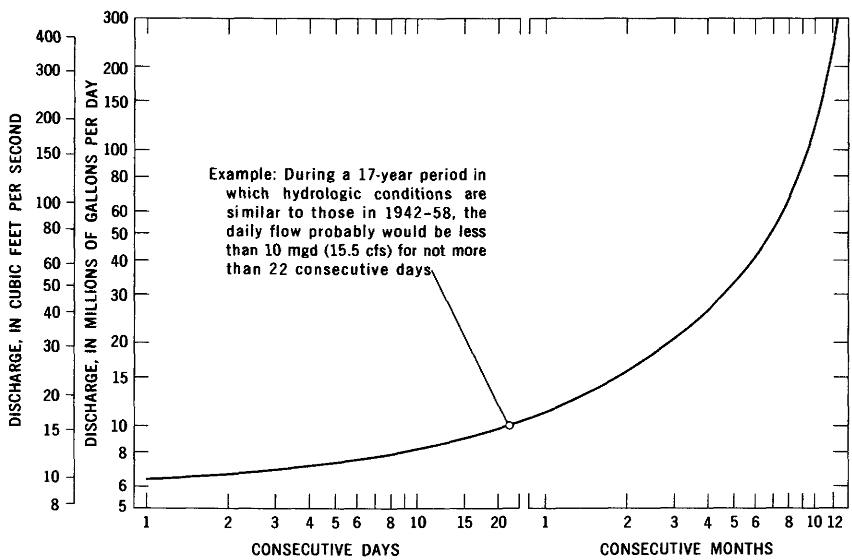

FIGURE 35.—Maximum period of deficient discharge, Pequabuck River at Forestville, 1942–58.

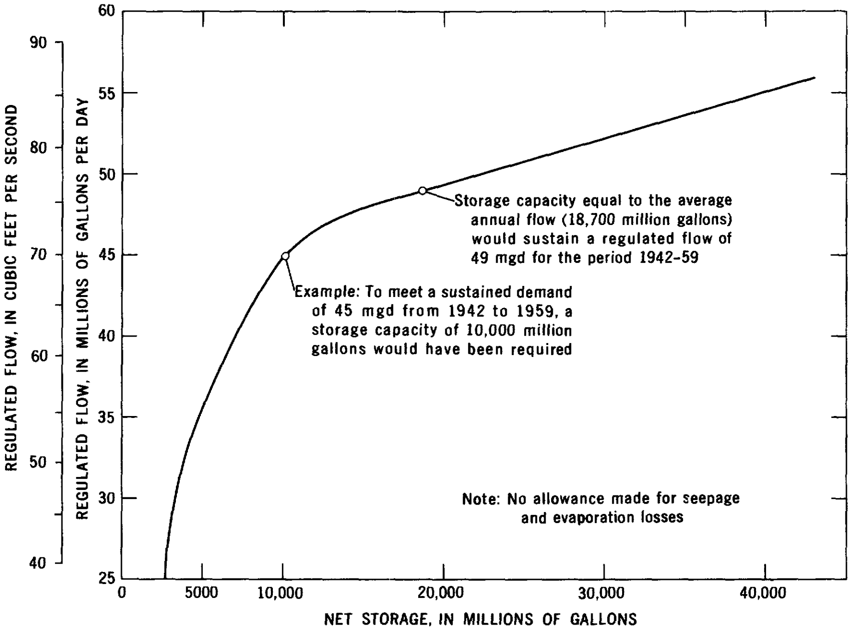

FIGURE 36.—Storage required to maintain flows, Pequabuck River at Forestville, 1942–59.

The flood of August 19, 1955, was the most outstanding flood in the history of the Pequabuck River basin. At Forestville it reached an altitude of 210.9 feet above mean sea level, 13 feet above the riverbed, and the flow was 11,700 cfs. Other major floods are given in table 8. A flood-frequency curve showing the average interval, in years, between floods that equal or exceed a given magnitude is shown in figure 37.

Generally, the chemical quality of water from the Pequabuck River at Forestville is very good (table 12). Although the interval between analyses was about 4 years, the chemical quality changed very little. A sample collected on May 3, 1956, contained 57 ppm of dissolved solids, and a sample collected on May 9, 1960, contained 65 ppm of dissolved solids. Hardness of the water averaged 24 ppm for three determinations (table 12). Comparison of the analyses discloses some differences in the concentrations of individual constituents, however, particularly iron and sulfate. These samples were collected during the spring runoff when discharge was high, so that dilution was a factor in maintaining the low concentrations. Some increase in the dissolved solids and hardness can be expected during low flow.

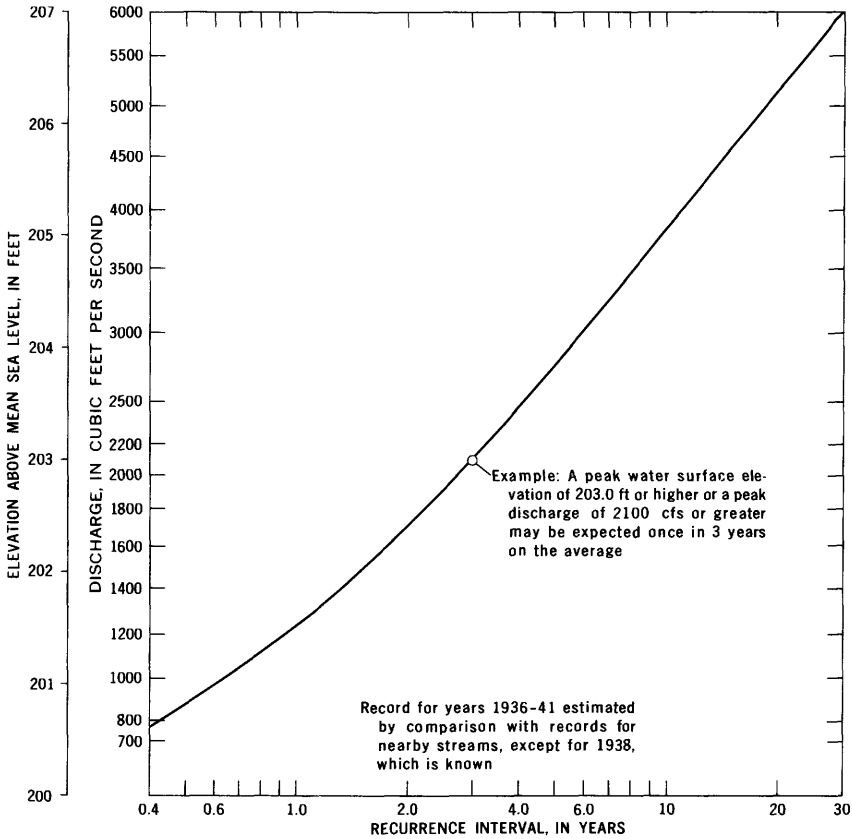

FIGURE 37.—Magnitude and frequency of floods, Pequabuck River at Forestville, 1936–59.

BURLINGTON BROOK

Burlington Brook, 8 miles north of Bristol, is 6.7 miles long and drains an area of 9.81 square miles. Although outside the immediate area of this report, its flow record is included as typical of the flow of small streams in the Bristol subarea. The brook has been considered as a possible source of water supply for the city of New Britain through its existing reservoir at Whigville on Copper Mine Brook, for it contains water of good quality. It is a mountain stream having steep slopes, gorges, and waterfalls. Its dry-weather flow is sustained at a relatively high level in contrast to the almost nonexistent dry-weather flow of Leadmine Brook in the Waterbury subarea. Flood runoff is rapid and peaks are high but of short duration.

TABLE 12.—*Chemical analyses, in parts per million, of water from Pequabuck River at Forestville*

	Date of collection		
	May 3, 1956	Apr. 6, 1960	May 9, 1960
Silica (SiO_2)	7.8		
Iron (Fe)	.34	0.23	
Manganese (Mn)	.00		
Calcium (Ca)	6.0		
Magnesium (Mg)	1.7		
Sodium (Na)	5.1		
Potassium (K)	1.3		
Bicarbonate (HCO_3)	13	12	25
Sulfate (SO_4)	12	20	9.4
Chloride (Cl)	5.1	5.8	
Fluoride (F)	.0		
Nitrate (NO_3)	7.0		
Dissolved solids, residue at 180°C	57		65
Hardness as $CaCO_3$:			
Calcium, magnesium	22	24	26
Noncarbonate	11		
Specific conductance micromhos at 25°C	85.4	82	94
pH	6.0	5.9	6.3
Color unit	7		
Temperature °F	54	42	61

The flow of Burlington Brook has been gaged near Burlington since September 1931 (fig. 13). A summary of streamflow data appears in table 8.

The flow characteristics of Burlington Brook are shown by the flow-duration curve in figure 38. Also shown for comparison are curves for both maximum and minimum percent of time specific daily discharges were equaled or exceeded in any year.

The low-flow frequency curve for Burlington Brook is shown in figure 39, and the curve showing the maximum period during which the flow was less than a specified discharge is shown in figure 40. Storage necessary to maintain specific outflow rates on Burlington Brook may be determined from figure 41.

Floods on Burlington Brook usually cause negligible damage because there is little of value near the brook except highway bridges. The flood of August 19, 1955, was by far the greatest experienced in recent years. At the gaging station the brook rose 9 feet, and the flow reached 1,690 cfs. A flood-frequency curve which shows the average interval in years between floods that equal or exceed a given discharge is shown in figure 42. Table 8 gives the major floods which have occurred on Burlington Brook since records began in September 1931.

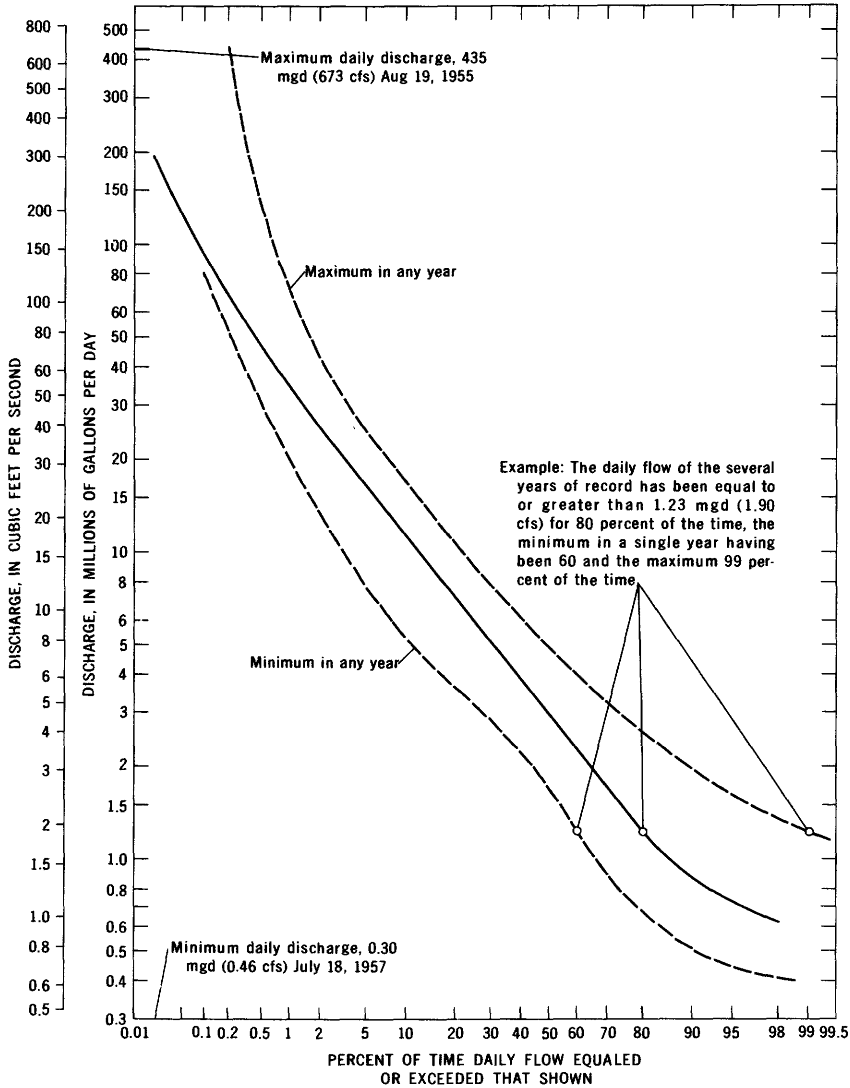

FIGURE 38.—Duration curve of daily flows, Burlington Brook near Burlington, 1932–59.

SAND AND GRAVEL AQUIFERS

A major sand and gravel aquifer occupies the lowland that extends north and south from Forestville to the boundaries of the town of Bristol (pl. 1). It is crossed by the Pequabuck River and extends as a narrow band of sand and gravel bordering the river eastward to the town boundary.

The thickness of the sand and gravel is variable owing to considerable relief in the land surface and the surface of the underlying

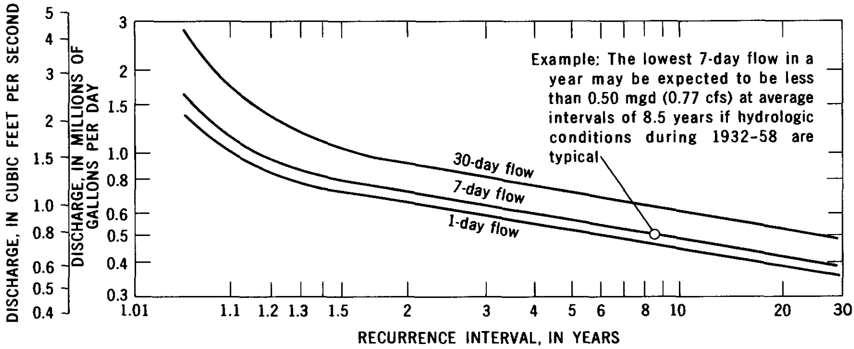

FIGURE 39.—Magnitude and frequency of annual low flows, Burlington Brook near Burlington, 1932–58.

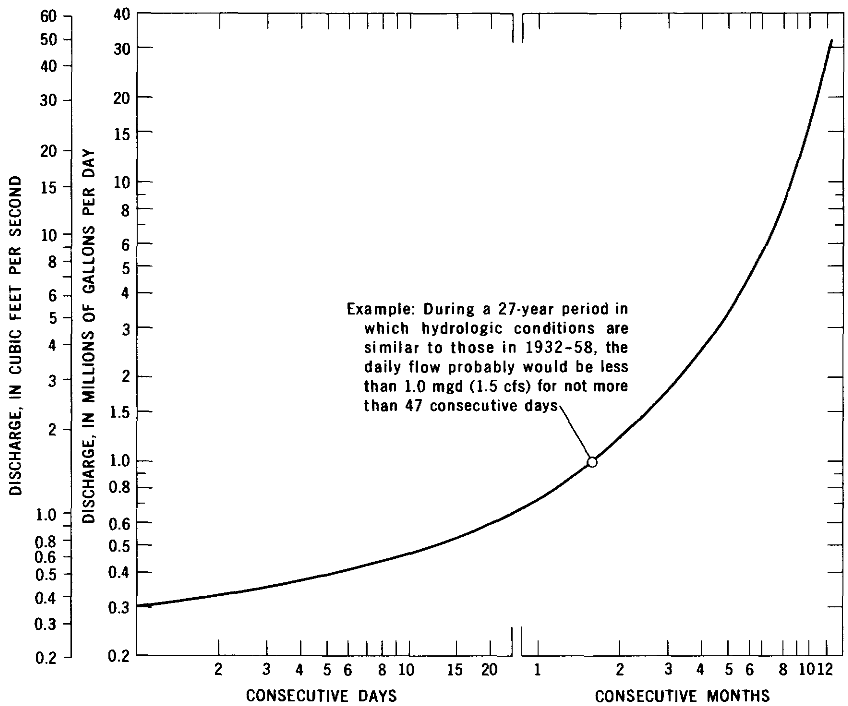

FIGURE 40.—Maximum period of deficient discharge, Burlington Brook near Burlington, 1932–58.

ground moraine and bedrock. The greatest known thickness is 72 feet at well Bs 148. The total thickness of unconsolidated material at any point in this area can be estimated from the contours in plate 1; this thickness would include the ground moraine, which does not yield

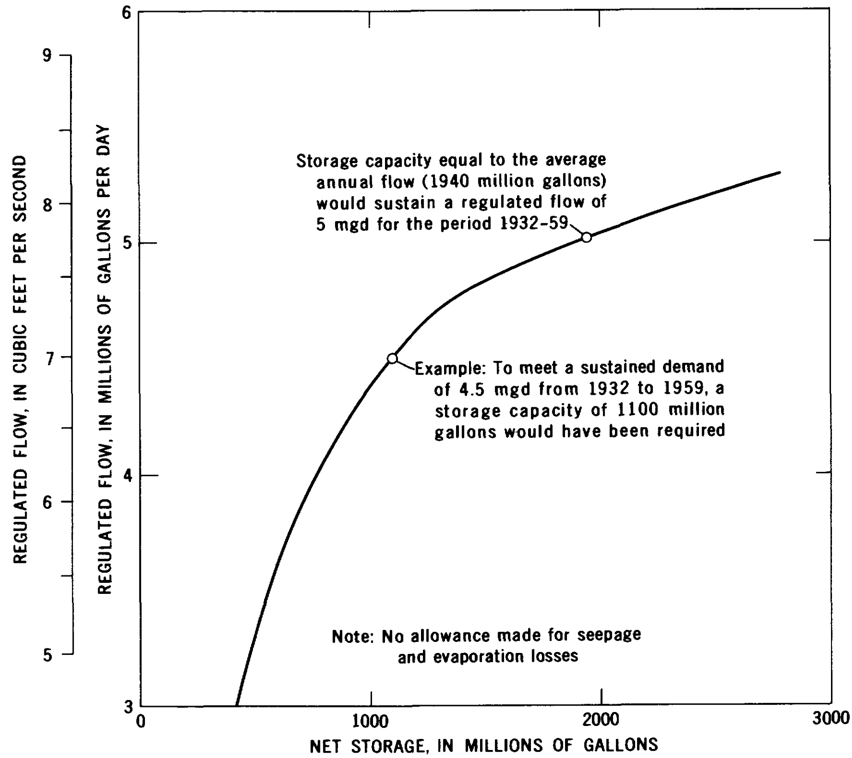

FIGURE 41.—Storage required to maintain flows, Burlington Brook near Burlington, 1932–59.

water to wells, as well as the sand and gravel, as illustrated by geologic section *E–E′*.

Discontinuous beds and lenses of pebble and cobble gravel are rather abundant in the upper 10 to 20 feet of the sand and gravel deposits. Medium and fine sand, however, usually make up the lower parts of exposures, and sand containing only a few gravel lenses is reported at depth in well logs.

This aquifer is capable of yielding large supplies of water, where beds of highly permeable materials are penetrated. The yields and specific capacities of six major supply or test wells, determined by pumping tests, are shown in the following table.

	Wells					
	Bs 92	Bs 123	Bs 148	Bs 149	Bs 150	Bs 198
Yield, gpm	300	200	1,400	300	300	150
Specific capacity, gpm per foot of drawdown	14	17	50	27	15	10.4

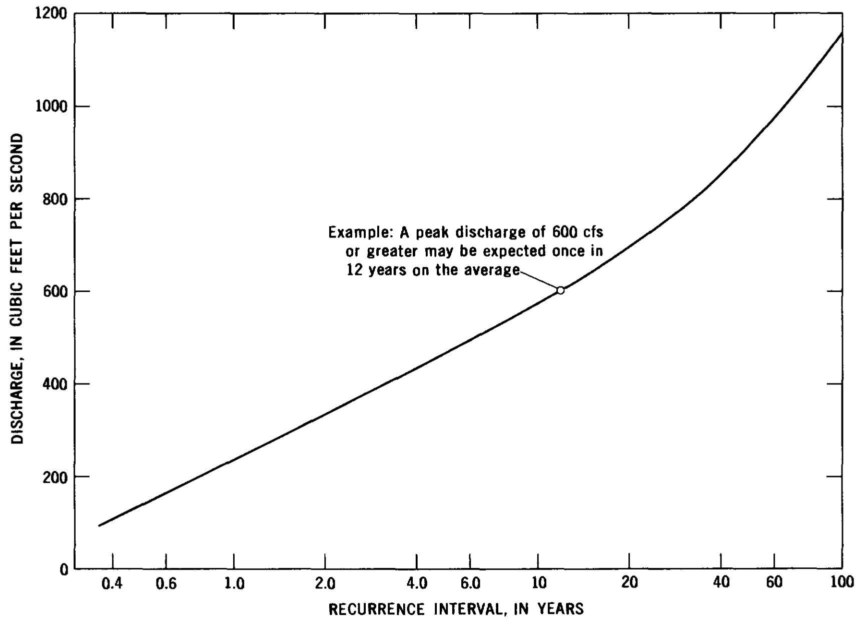

FIGURE 42.—Magnitude and frequency of floods, Burlington Brook near Burlington, 1932–59.

Complete records of these wells are given in table 7. Because of the pronounced vertical and horizontal variations in the lithology of these deposits, two wells only a few hundred feet apart may penetrate materials of different hydrologic characteristics. Rather extensive preparatory test drilling has been required before constructing large-capacity wells in these deposits; the drilling indicates that only at scattered locations is the saturated section of well-sorted medium to coarse sand and gravel thick enough to permit yields of 150 gpm or more. Most of the material is apparently too fine grained or poorly sorted to be highly permeable. Nevertheless, small-diameter screened test wells at several locations yielded from 5 to 75 gpm. Yields of this order could probably be obtained from these deposits in many places by means of properly constructed drilled, driven, or dug wells.

Water in these deposits generally occurs under unconfined or water-table conditions. Depth to the water table is generally 5 to 15 feet, although beneath a few of the higher sand hills and terraces it might be as great as 40 feet. North of the Pequabuck River, the saturated thickness is likely to be greater in the central part of the lowland than in the higher marginal deposits. Also, in the central part of the lowland, more of the coarse near-surface beds are likely to be saturated. Wells placed close to the Pequabuck River or its perennial tributaries from the north, such as Copper Mine Brook, can induce recharge from these streams. Among the wells that obtain part of their supplies in this manner are Bs 92 and 148.

At White Bridge, about 1½ miles north of Forestville, the city of New Britain Water Department operates a well installation which depends substantially on induced recharge. A line of 20 closely spaced wells 25 to 45 feet deep extends between Copper Mine and Polkville Brooks, 20 feet southeast of and parallel to a ditch which was constructed to connect the two streams. A large concrete caisson or chamber with an open bottom, and an infiltration pond connected to Copper Mine Brook and to the ditch, make up the rest of the system. The wells are pumped by suction into the caisson, from which water is pumped into the pipeline to New Britain. Local precipitation, the normal flow of ground water southeastward and the water infiltrating into the ground from the ditch, the artificial pond, and the two brooks provide the system with a yield of 3.3 mgd. Although the wells are only about 25 feet apart, interference between them must be slight because drawdown is not excessive.

A broad band of sand and gravel deposits extends continuously from the business district of Bristol northward to the city line and westward along the Pequabuck River valley to Terryville; from there, it extends northward along the Poland River valley (pl. 1). The maximum known thickness is 225 feet in Bristol and 67 feet in Plymouth. Surface relief is considerable and the bedrock floor beneath the deposits is irregular; so the deposits vary considerably in thickness within short distances. The bedrock contours on plate 1 show the general aspect of the bedrock surface.

Many exposures in these sand and gravel deposits reveal a wide range in grain size—from coarse gravel to very fine sand. Some beds are well sorted but many are not. Beds are commonly lenticular, warped, and contorted. Such materials are apparently most common in the uppermost 10 to 40 feet of the deposits and are especially common near valley margins, where the deposits are relatively thin. Logs of wells indicate that where the deposits are relatively thick away from the valley margins the materials at depth are largely fine and very fine sand and silt but contain some interbedded material of medium sand to gravel size.

Depth to water varies considerably from place to place within the sand and gravel deposits in northwest-central Bristol and eastern Plymouth. The water table is generally only a few feet below the surface near where these deposits overlap the less permeable ground moraine along the valley margins. Beneath the flat valley bottoms, it stands about at stream level and close to the land surface. Within the terrace deposits that lie between the valley margins and the valley bottoms, however, the water table slopes uniformly rather than paralleling the terraced land surface. In Bristol, where the Pequabuck River now flows 150 feet or more lower than the 650-foot surface of the sand and gravel terraces, this uniform slope brings the water table far below the surface along outer or valleyward sections of these terraces, and much of their relatively great thickness of sediment is unsaturated. Consequently, the high-level deposits have been little utilized as sources of ground water in Bristol. In and north of Terryville, on the other hand, where the relief is not as great, depth to water is everywhere less than 35 feet, and small saturated thicknesses occur chiefly near the valley margins.

The sand and gravel deposits in northwest-central Bristol and eastern Plymouth are capable of yielding several hundred gallons per minute to wells in some places. In general, the most favorable areas are in the valley bottoms near the Pequabuck and Poland Rivers and Marsh Brook. Here the saturated thickness is at a maximum, as the water table is near the surface and the present valleys approximately coincide with the axes of the buried preglacial bedrock valleys. Wells can draw on the water that is in transit through the valleys in streams and in ground-water underflow. A substantial amount of ground water also flows to the valley bottoms from the terrace deposits bordering them, as indicated by the large yields of springs Bs 4sp and 5sp at points where the water table intersects the land surface at the base of the terrace slope. The locations of these springs appear on plate 1; brief records are given in the following table.

Spring number	Yield (gpm)	Use	Source of information
Bs 4sp	250	Industrial cooling and cleaning.	Plant engineer.
5sp	100(?)	Unused. Formerly public supply and bottling works.	Palmer (1921, p. 93).

Only a few large-capacity wells obtain water from these deposits. Three such wells are described in table 7 from which the following data are summarized:

	Wells		
	Bs 4	Pm 1	Pm 2
Depth ft	75	67	59
Yield gpm	800	438	488
Specific capacity gpm per foot of drawdown	25	12	15

In addition, several test wells and small industrial wells finished in sand and gravel along the Pequabuck valley were pumped at 35 to 100 gpm; this yield indicates that even in the more favorable areas permeability and saturated thickness are not adequate for large yields at many sites.

The sand and gravel deposits along the Pequabuck River upstream from Terryville and along Marsh Brook above East Plymouth are probably not significant aquifers. Sand and gravel deposits upstream from Terryville along the Poland River extend to the north boundary of the town, but saturated thickness is likely to be small north of St. Mary's cemetery (1 mile upstream from Terryville).

Favorable drilling sites may be present locally in the deposits near Birge Pond and Polkville Brook in Bristol although these deposits are not as thick as those in the Pequabuck valley. Highly permeable material, if present, is spottily distributed.

The chemical quality of water from sand and gravel deposits in the Bristol subarea is generally very good. A moderate quantity of dissolved solids is in solution, and the hardness of the water is generally less than 50 ppm (fig. 43).

Concentrations of calcium, magnesium, sodium, and potassium are each less than 10 ppm, and those of bicarbonate alkalinity less than 50 ppm. Representative chemical analyses of ground water from sand and gravel deposits and from crystalline bedrock are given in table 13.

SEDIMENTARY BEDROCK OF TRIASSIC AGE

In the eastern part of the city of Bristol, the glacial deposits are underlain by sedimentary bedrock of Triassic age. The contact between the sedimentary bedrock and the older crystalline rocks to the west is shown on plate 1.

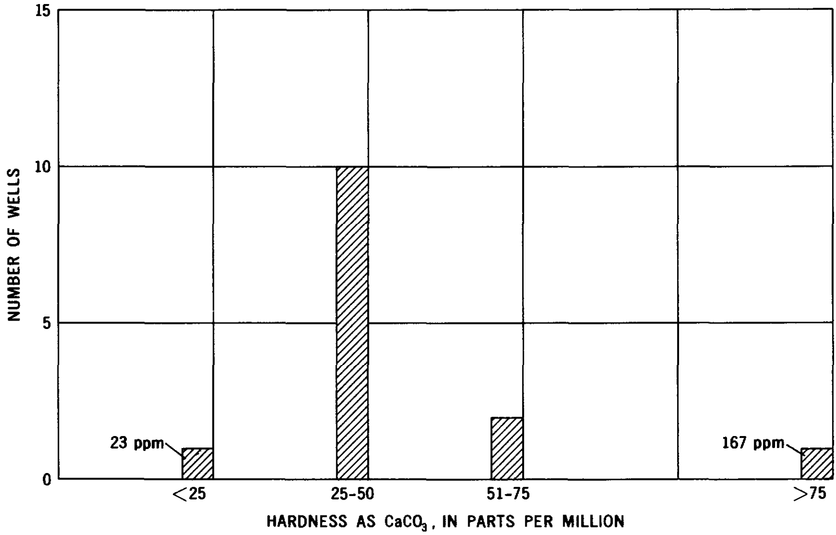

FIGURE 43.—Variation in hardness of water from sand and gravel deposits in the Bristol subarea.

TABLE 13.—*Analyses of water, in parts per million, from sand and gravel and crystalline bedrock in the Bristol subarea*

	Well Bs 78	Well Bs 46
Aquifer	Sand and gravel.	Crystalline bedrock.
Date of collection	Sept. 23, 1957	Sept. 23, 1957
Silica (SiO_2)	24	27
Iron (Fe)	.08	.06
Manganese (Mn)	.01	.01
Calcium (Ca)	9.6	17
Magnesium (Mg)	3.3	7.8
Sodium (Na)	7.1	6.7
Potassium (K)	2.6	1.4
Bicarbonate (HCO_3)	36	76
Sulfate (SO_4)	11	11
Chloride (Cl)	7.3	9.8
Fluoride (F)	.2	.1
Nitrate (NO_3)	5.7	4.7
Dissolved solids, residue at 180°C	86	119
Hardness as $CaCO_3$:		
Calcium, magnesium	38	75
Noncarbonate	8	12
Specific conductance micromhos at 25°C	117	119
pH	6.0	6.9
Color units	3	2
Temperature °F	54	53

The sedimentary bedrock can be divided into two lithologic units. Beneath the lowland just east of the crystalline-rock contact are beds of light-gray conglomerate, conglomeratic arkose, coarse-grained gray arkose, and dark-colored shale. Beneath Redstone Hill and the other hills along the east border of the town, the predominant rock type is a fine- to medium-grained red clayey feldspathic sandstone interbedded with siltstone and shale.

The amount of pore space in the beds of arkose, which are the best sorted of the sedimentary rocks, averages no more than 5 percent. Intergranular permeability is small in the arkose and is virtually nonexistent in the shale, siltstone, and clayey feldspathic sandstone. Thus, although some water may be stored in pore spaces, the principal avenues of water movement are tabular openings, such as joints and bedding-plane partings. Because the joints and partings are unevenly distributed and the size of their openings is variable, the yields of wells in these rocks may differ unpredictably within relatively short distances, depending on the number and size of such openings intersected by each well.

The chances are good of obtaining an adequate domestic water supply (3 gpm or more) at any well site. Numerous domestic drilled wells have been finished in the sedimentary bedrock of eastern Bristol, most being on the hills along the east side of the town. Records of 28 such wells were examined; in all but two the reported yield is between 4 and 22 gpm, and the largest reported yield is 40 gpm. Of 18 computed specific capacities, 16 were less than 0.4 gpm per foot of drawdown—adequate for most domestic supplies. Of the 28 wells, all but 6 are between 100 and 175 feet in depth, and only 1 penetrated more than 120 feet of rock below the bottom of the casing. The following table gives the median depth, rock thickness penetrated, yield, and specific capacity of these wells, and, for comparison, gives the corresponding data obtained from a study (Randall, 1964) of similar wells in cities farther northeast.

TABLE 14.—*Summary of records of domestic and farm wells finished in Triassic sedimentary bedrock*

Area	Median depth		Median rock thickness below casing		Median reported yield		Median specific capacity	
	Feet	Number of wells	Feet	Number of wells	Gpm	Number of wells	Gpm per ft	Number of wells
Eastern Bristol	139	28	88	27	10	27	0.15	18
Six towns northeast of Bristol	150	310			8	[1] 312	.17	118
	[2] 120	77	[2] 93	70				

[1] Includes industrial, public supply, and irrigation wells also.
[2] Computed from wells on hills similar to those in eastern Bristol.

The differences between the two sets of data are small; they probably reflect minor differences in lithology, but may be due in part to the smaller number of wells sampled in Bristol. Comparison of these data with corresponding data for wells in crystalline bedrock of the Waterbury-Bristol area, given on page J79, shows clearly that the sedimentary bedrock is the more productive aquifer. Although the median rock thickness penetrated is nearly the same in the two rock types, wells in sedimentary bedrock have considerably larger average yields and specific capacities.

It is difficult to evaluate the chances of obtaining large yields from the Triassic sedimentary bedrock. The yields of most of the domestic wells referred to above doubtless could have been increased somewhat by drilling deeper and developing more fully, had there been reason to do so. The consistently small specific capacities, however, indicate that large yields could not be obtained without large drawdowns, which increase pumping costs and cause greater interference with nearby wells. Most commercial and industrial wells are drilled to obtain relatively large supplies; the results of drilling three such wells in the sedimentary bedrock of eastern Bristol are summarized in the following table:

Well	Depth (feet)	Rock thickness below casing (feet)	Yield (gpm)	Drawdown (feet)	Specific capacity (gpm per ft)
Bs 3	256	239	110	?	----------
125	223	195	10	?	----------
147	608	539	20	207	0.1

Complete records of these wells appear in table 7. The location of well Bs 3 (adjacent to the Pequabuck River and perhaps also to a fault) may be responsible for its relatively large yield. Study of wells in towns northeast of Bristol (Randall, 1964) indicates that in that area yields of 25 to 35 gpm are fairly readily obtainable from Triassic sedimentary bedrock, and yields of about 100 gpm can be obtained from the majority of wells 300 to 600 feet deep, although generally with large drawdowns. The water-yielding capacity of the sedimentary rocks varies noticeably from place to place, however, and the record of well Bs 147 serves as a reminder that some wells are drilled to depths of several hundred feet without tapping sufficient major fractures to permit more than small yields. In eastern Bristol, the arkose of the lowland may be a little more favorable for obtaining large yields than the rocks beneath the hills along the east side of the town.

In general, the upper part of the bedrock is the most productive, as the number and size of fractures tends to decrease with depth. The depth at which the drilling of an inadequate well should be stopped is always a matter of great concern. The relation between depth and yield is not a simple one, and drilling deeper does not necessarily result in a significant increase in yield. Data from elsewhere in the Triassic sedimentary bedrock of Connecticut (Cushman and others, 1965) indicate that unless a well increases appreciably in yield between 400 and 500 feet, it is not generally worthwhile to drill deeper.

Static water levels in bedrock wells on the hills along the east side of Bristol are generally between 10 and 30 feet below the land surface. Data for the lowland areas are sparse but indicate that more variability of water levels is possible because of the irregular surface topography.

OTHER SOURCES OF GROUND WATER

The bedrock units in central and western Bristol are referred to as crystalline rocks. The contact between them and the younger Triassic sedimentary bedrock to the east is shown on plate 1. The water-yielding properties of crystalline rocks are described in the section of this report on the "Rural subarea"; in general, only small supplies can be obtained from most wells that penetrate them. Yields greater than 20 gpm are reported for less than 10 percent of the wells in crystalline bedrock in the Bristol subarea. The largest yield was 85 gpm; the average yield was 10 gpm.

Ground moraine is an unconsolidated glacial deposit of variable thickness which mantles the bedrock throughout the Bristol subarea and which is interrupted locally by bedrock outcrops. It lies at the surface on most hills, as shown in plate 1 and is in turn mantled by glacial sand and gravel in most valleys. Its water-yielding properties are discussed in the section of this report on the "Rural subarea"; in general, it is a poor aquifer in which only large-diameter dug wells yielding less than 5 gpm have been constructed.

RURAL SUBAREA

SAND AND GRAVEL AQUIFERS

Sand and gravel deposits occur along several valleys in rural parts of the Waterbury-Bristol area. Of these, the deposits along Todd Hollow and lower Hancock Brooks constitute the best aquifer.

Sand and gravel deposits extend from near the Waterbury-Plymouth town line northward along Hancock and Todd Hollow Brooks to about 1 mile south of U.S. Highway 6. Compact poorly sorted pebble to boulder gravel is exposed locally along the valley margins, but beds of regularly bedded pebble gravel and medium to very fine sand are exposed in pits in the center of the valley and may form most of the valley fill. Seven wells just west of the intersection of Waterbury and Greystone Roads are finished with open-end casings in gravel at depths of 50 to 90 feet. Yields of 5 and 8 gpm are reported for two of these wells. Much larger yields could be obtained from properly developed screened wells in these materials. In addition, a well at the intersection of Todd Hollow Road and South Street penetrated about 85 feet of "hardpan, medium sand, and gravel" above bedrock, as reported in the driller's log. Accordingly, it appears that the sand and gravel fill of these valleys is potentially a major aquifer, with yields as large as several hundred gallons per minute possible.

Sand and gravel deposits are present in the valley of upper Hancock Brook, just south of the southern end of the Terryville railroad tunnel, and in the valley of Spruce Brook at the Waterbury-Plymouth line. Cobble and boulder gravel is common at the surface in the valley of Hancock Brook. The saturated thickness in these deposits probably is thin, but small supplies may be obtainable from suitable wells. Sand and gravel deposits in the valley of Hop Brook in southwestern Waterbury probably also extend only a short distance below the water table; their potential is unknown but probably is small.

GROUND MORAINE

Ground moraine is an unconsolidated glacial deposit which occurs as a discontinuous mantle over the bedrock throughout the Waterbury-Bristol area. It consists predominantly of glacial till ("hardpan"), which is a nonsorted mixture of gravel, sand, silt, and clay in various proportions. Boulders as large as several feet in diameter are a common constituent. Small pockets of stratified, water-deposited material occur within accumulations of till in some places and are included as part of the ground moraine.

Ground moraine occurs at the surface on most hills, as shown in plate 1. It is variable in thickness from place to place; bedrock outcrops protrude through it in many places, particularly along ridges, and it is commonly between 0 and 30 feet thick. It is 40 or more feet thick, however, in some localities, and thicknesses as great as 139 feet have been reported. Where glacial sand and gravel deposits occur at the surface, a layer of ground moraine commonly lies between these deposits and the underlying bedrock.

Because of its wide range in grain size and its poor sorting, till is relatively impermeable and will not yield water rapidly to wells. It is rarely possible, consequently, to complete drilled or driven wells successfully in the ground moraine, but many large-diameter dug wells provide adequate domestic and farm supplies. Such wells generally yield less than 5 gpm, but because of their large diameter, they are able to store enough water to compensate for the slow rate of inflow from the till. The pockets of stratified sand and gravel within the ground moraine are much more permeable than the till and yield water readily where they are below the water table, but they are generally too small and scattered to be of consequence.

Water-Supply Papers 397 (Ellis, 1916) and 466 (Palmer, 1921) were prepared at a time when dug wells outnumbered other types of wells. Water-Supply Paper 466 contains records of a large number of dug wells finished in ground moraine in Bristol, Plymouth, and Wolcott; the locations of these wells are shown on maps accompanying the paper. A discussion of the water-yielding properties of the ground moraine also is included. Similar but less extensive information for Waterbury may be found in Water-Supply Paper 397 (Ellis, 1916). The data in the following table are summarized chiefly from these two reports.

TABLE 15.—*Summary of records of dug wells, in feet, finished in ground moraine*

	Bristol	Plymouth	Wolcott	Waterbury	Waterbury
Number of wells measured	[1] 138	[1] 112	[1] 80	[2 3] 15	[3 4] 52
Well depth:					
Minimum	5.0	7.0	6.9	11.8	5.5
Maximum	40.0	30.9	33.1	39.9	50.9
Mean	19.6	17.0	16.8	19.3	20.4
Static water level below land surface:					
Minimum	3.0	1.6	3.6	3.7	2.1
Maximum	38.2	28.7	26.4	29.5	49.0
Mean	15.6	10.0	10.7	10.7	14.1
Number of wells reported to have failed	17	41	24	1	21
Number of wells reported unfailing	37	54	40	0	10

[1] Individual measurements given in Water-Supply Paper 466 (Palmer, 1921).
[2] Individual measurements given in Water-Supply Paper 397 (Ellis, 1916).
[3] There records were distinguished from records of dug wells finished in sand and gravel by A. D. Randall, on the basis of the geologic map accompanying the present report.
[4] Measurements made by the U.S. Geol. Survey, mostly during October 1944: well records on file at Connecticut office of the Ground Water Branch, U.S. Geol. Survey: most wells are in southern and eastern Waterbury.

CRYSTALLINE BEDROCK

The glacial deposits are underlain by crystalline bedrock throughout the Waterbury-Bristol area, except in eastern Bristol where they are underlain by sedimentary bedrock of Triassic age. The contact between these two rock types is shown on plate 1. Because crystalline bedrock is the only significant aquifer in much of the report area outside of the urban valleys in Waterbury and Bristol, it is discussed under the "Rural subarea."

According to the Preliminary Geological Map of Connecticut (Rodgers and others, 1959), the crystalline rocks of the Waterbury-Bristol area include three units: the Waterbury and Bristol Gneiss of Gregory (1906) and the Hartland Formation. The Waterbury Gneisses of Gregory (1906), which underlies much of the city of Waterbury, is described as a complex of strongly banded gneiss and less abundant medium-grained schist, variable in composition and structure. The Bristol Gneiss of Gregory (1906), which underlies central and north-central Bristol, is a granitoid gneiss composed chiefly of feldspar, quartz, and biotite. The rest of the area is underlain by the Hartland Formation, which consists typically of interlayered mica quartzite and schist but contains abundant coarse-grained muscovite schist in eastern Wolcott and locally includes small gneiss bodies. The three units are discussed together in this report because their water-yielding properties are nearly the same. Intergranular porosity is of the order of 1 percent; consequently, water can occur and move only in the narrow openings along joints or fractures in the rock, and the yield of a well is determined by the number and size of such openings intersected. Because the fractures are unevenly distributed and the size of their openings is variable, well yields may differ unpredictably from place to place. Ellis (1909) presented a thorough discussion of jointing and its relation to ground water in the crystalline rocks of Connecticut.

The chances are good of obtaining at least 3 gpm from the crystalline bedrock at any well site. A supply of this size would be adequate for most domestic, farm, and small businesses. Of 251 domestic and farm wells finished in crystalline rock for which records were available, only 36 (14 percent) are reported to yield less than 3 gpm. As shown by figure 44, the yields of most wells are between 3 and 10 gpm; only two wells are reported to yield more than 22 gpm. Most domestic and farm wells (88 percent) are between 60 and 180 feet deep, as shown by figure 45, and very few penetrate more than 150 feet of rock below the bottom of the casing. The following table gives the median depth, rock thickness penetrated, yield, and specific capacity of these wells.

The following medians summarize the records of domestic and farm wells finished in crystalline bedrock in the Waterbury-Bristol area:

Depth of 257 wells	ft	116
Thickness of rock below casing in 249 wells	do	82
Reported yield of 251 wells	gpm	4
Specific capacity of 107 wells	gpm per ft	0.06

Corresponding data for domestic and farm wells in sedimentary bedrock are given in table 14. Comparison of the two sets of values shows clearly that the sedimentary bedrock is the better aquifer. Although the median rock thickness penetrated is nearly the same for the two rock types, wells in crystalline bedrock have considerably smaller yields and specific capacities, on the average, than wells in sedimentary bedrock.

Large water supplies are rarely obtained from crystalline bedrock. Of 53 industrial, commercial, and public-supply wells for which rec-

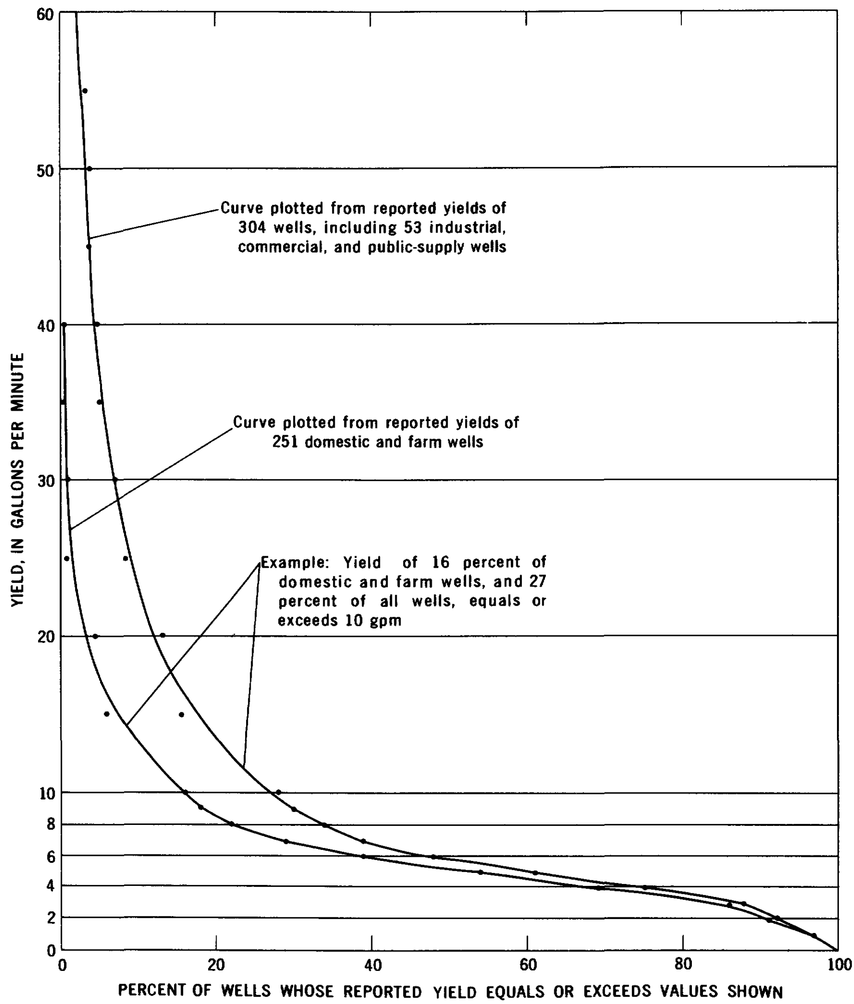

FIGURE 44.—Cumulative frequency curves of yield of wells finished in crystalline bedrock in the Waterbury-Bristol area.

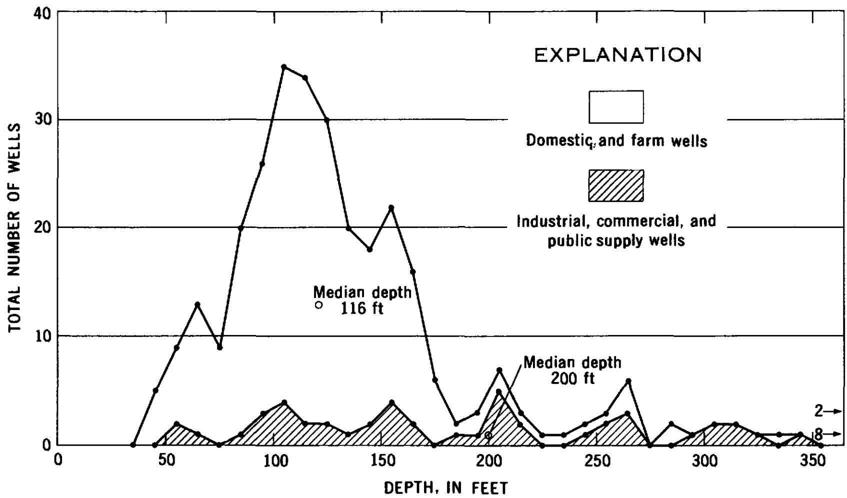

FIGURE 45.—Depths of wells in crystalline bedrock in the Waterbury-Bristol area.

ords are available, only 11 (21 percent) are reported to have been pumped at 50 gpm or more, and only 6 (11 percent) provided more than 55 gpm. The median reported yield is 20 gpm. The largest yield was obtained from well Wb 53 in downtown Waterbury (table 7), which was reportedly pumped at 150 gpm; the driller of this well stated that at a depth of 110 feet, his tools dropped about 5 feet without drilling and that most of the water was obtained from this extraordinarily large cavity. Reported yield, however, is not an entirely satisfactory measure of well performance as some records were based on the owner's memory years after the well was drilled and tested. Also, when some wells were tested the pumping levels were deep but still considerably above the bottoms of the wells, so that the quoted yields may not have been the maximum obtainable. If the maximum obtainable yields of the 53 wells mentioned above were accurately known, the median yield would probably be somewhat greater than 20 gpm. Available specific-capacity data suggest that few wells would provide more than 60 gpm, however.

Specific capacity, which takes into account both yield and drawdown, is a useful measure of well performance and aquifer potential. Specific capacities of 107 domestic wells finished in crystalline bedrock in the Waterbury-Bristol area are mostly between 0.01 gpm per foot of drawdown and 0.10 gpm per ft, and all but 14 percent are less than 0.17 gpm per ft. This means that a pumping rate of 10 gpm would require at least 60 feet of drawdown in all but the very best wells, and some of the poorest wells would yield as little as 1 gpm with 100 feet of drawdown. Specific capacities could be calculated for only 12 industrial, commercial, and public-supply wells. Probably because of the considerably greater average depth of these wells (see fig. 45), most of their specific capacities are higher than the average for domestic wells. Of the 12 specific capacities, however, 9 are less than 0.25 gpm per ft, which means that less than 25 gpm would be obtained per 100 feet of drawdown in 3 out of 4 of these wells. The largest reliable specific capacity is 1.4 gpm per ft, obtained in well Wc 12 during an 11-hour pumping test. These data indicate clearly that large drawdowns and deep pumping levels are characteristic of wells in crystalline bedrock. The wide spread in specific capacity, even among wells of similar depth, is due largely to the wide variation in occurrence and size of water-yielding fractures.

The depth to water in wells in crystalline bedrock is generally between 5 and 25 feet below the land surface. Water levels are as deep as 40 to 90 feet in a few places, however, chiefly below hills or terraces composed of glacial deposits, where the bedrock lies at considerable depth. For example, deep water levels should be expected in bedrock wells near the outer edge of the belt of high sand terraces north of the Pequabuck River in Bristol.

Water from crystalline bedrock may contain more dissolved solids and be harder than water from sand and gravel aquifers. The chemical quality of ground water is influenced by a number of variables, such as the solubility of the minerals that make up the rocks and deposits, the length of time the water is in contact with the rocks, and the solvent capability of the water itself. An analysis of water from each source is given in table 13. The water from the crystalline rock had a dissolved-solids content of 119 ppm and a fairly high percentage of calcium and magnesium, causing the water to be moderately hard. The water from the sand and gravel had a dissolved-solids content of 86 ppm and, since it contained considerably less calcium and magnesium, was soft. Although the data are limited, they suggest that water from crystalline rock in the Bristol subarea will be considerably harder than water from sand and gravel deposits.

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