WATER RESOURCE INVENTORY OF CONNECTICUT

PART 7

UPPER CONNECTICUT RIVER BASIN

BY

ROBERT B. RYDER, MENDALL P. THOMAS, LAWRENCE A. WEISS

U.S. GEOLOGICAL SURVEY

PREPARED BY THE
U. S. GEOLOGICAL SURVEY
IN COOPERATION WITH THE
CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION

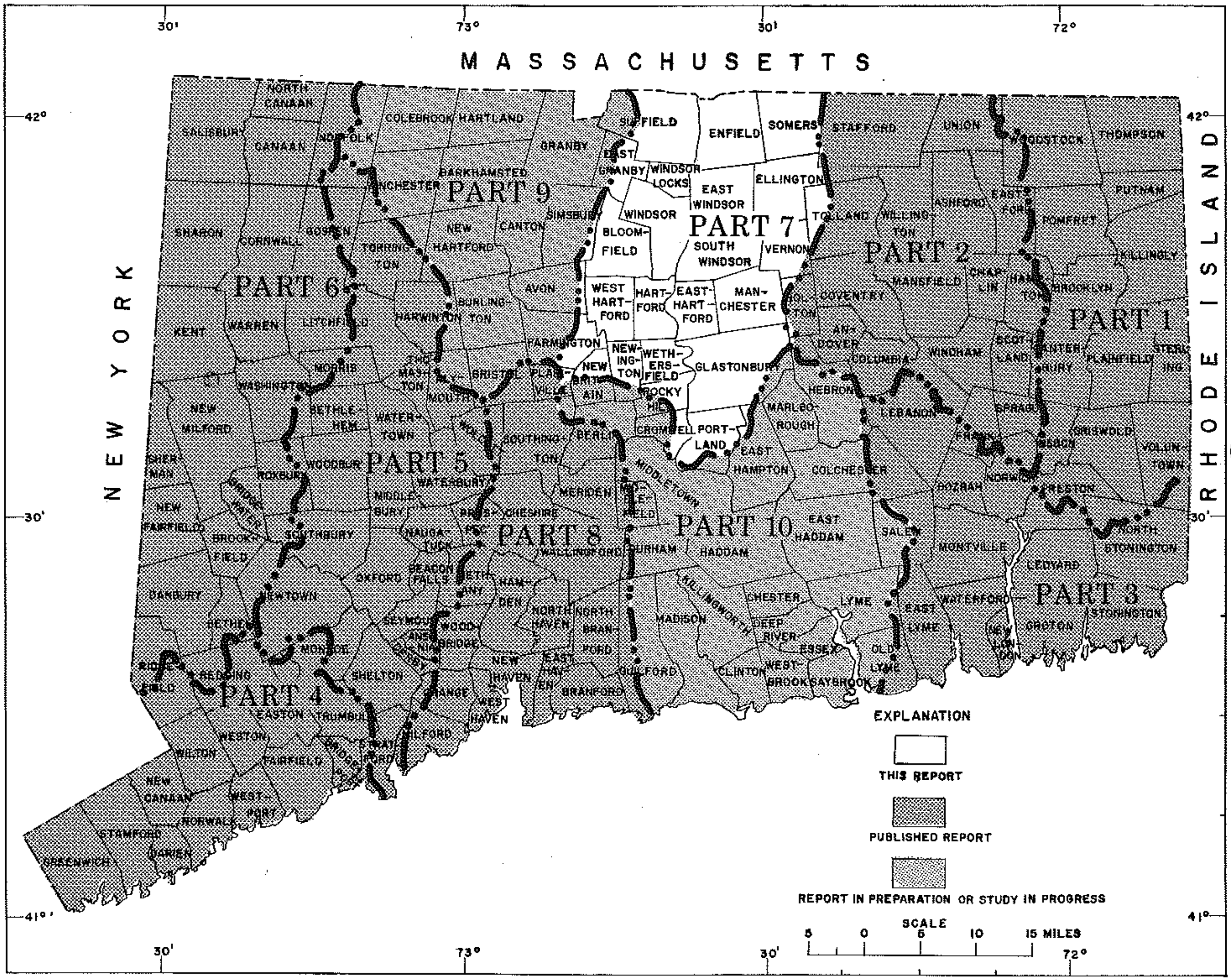
CONNECTICUT WATER RESOURCES BULLETIN NO. 24

1981

COVER PHOTO.--The Connecticut River, the largest river in New England, at Hartford, Connecticut. At this point the Connecticut River drains an area of approximately 10,500 square miles. The flow, as it enters the State, has averaged about 10,580 million gallons per day over the last 52 years. The maximum daily discharge, 182,200 million gallons per day, occurred on March 20, 1936, and the minimum, 625 million gallons per day, occurred on October 20, 1963.

The Connecticut River is one of the State's most valuable resources. It has extensive waterborne commerce, supports significant fish populations, and receives and assimilates thermal and other waste-water discharges from towns and industry.

Photograph courtesy of Aero Graphics Corporation, Box 248, Bohemia, New York, 11716.



THE WATER RESOURCES INVENTORY OF RIVER BASINS IN CONNECTICUT

PART 1-Quinebaug River Basin

PART 2-Shetucket River Basin

PART 3-Lower Thames and Southeastern Coastal Rirer Basins

PART 4-Southwestern Coastal River Basins

PART 5-Lower Housatonic River Basin

PART 6-Upper Housatonic River Basin

PART 7-Upper Connecticut River Basin

PART 8-Quinnipiac River Basin

PART 9-Farmington River Basin

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SUMMARY

The 508 square miles of the upper Connecticut River basin in north-central Connecticut include the basins of four major tributaries: the Scantic, Park, and Hockanum Rivers, and the Farmington River downstream from Tariffville. Precipitation over this area averaged 44 inches per year during 1931-60. In this period, an additional 3,800 billion gallons of water per year entered the basin in the main stem of the Connecticut River at the Massachusetts state line, about 230 billion gallons per year in the Farmington River at Tariffville, and about 10 billion gallons per year in the Scantic River at the Massachusetts state line. Some water was also imported from outside the basin by water-supply systems. About half the precipitation, 22.2 inches, was lost from the basin by evapotranspiration; the remainder flowed out of the study area in the Connecticut River at Portland.

Variations in streamflow at 41 long-term continuous-record gaging stations are summarized in standardized graphs and tables that can be used to estimate streamflow characteristics at other sites. For example, mean-flow and two low-flow characteristics: (1) the 7-day annual minimum flow for 2-year and (2) 10-year recurrence intervals, have been determined for many partial-record stations throughout the basin.

Of the 30 principal lakes, ponds, and reservoirs, two have usable storage capacities of more than 1 billion gallons. The maximum safe draft rate (regulated flow) of the largest of these, Shenipsit Lake at Rockville, is 6.5 million gallons per day for the 2-year and 30-year recurrence intervals (median and lowest annual flow).

Floods have occurred within each month of the year but in different years. The greatest known flood on the Connecticut River was in March 1936; it had a peak flow of 130,000 cubic feet per second at Hartford. Since then, major floods have been reduced by flood-control measures.

The major aquifers underlying the basin are composed of unconsolidated materials (stratified drift and till) and bedrock. Stratified drift overlies till and bedrock in valleys and lowlands in the eastern and western parts and in most of the broad central valley. The stratified drift generally ranges in thickness from 10 feet in small valleys to more than 200 feet in the Connecticut River Valley. Bedrock underlies the entire basin and is composed of (1) interbedded sedimentary and igneous rocks and (2) crystalline rocks.

Ground-water sources yield from several million gallons per day from large well fields to 1 gallon per minute from single wells. Yields of 100 gal/min or more are most commonly obtained from screened wells tapping stratified-drift aquifers; amounts can be calculated by use of a series of graphs in conjunction with estimates of aquifer transmissivity and thickness. Eighteen areas underlain by good aquifers are selected as the most favorable locations for large-scale development of ground water. Selection of these areas is based on estimates of aquifer characteristics and the amount of water potentially available from induced infiltration of streamflow at low-flow conditions.

Small to moderate water supplies can generally be obtained from any of the aquifers. Wells in bedrock yield at least a few gallons per minute at most sites. The probability of obtaining an adequate yield for domestic supply is greater in sedimentary than in crystalline bedrock and is also greater in stratified-drift overburden than in till.

Where unaffected by man's activities, the water is of the calcium magnesium bicarbonate type, is generally low to moderate in dissolved-solids concentration, and ranges from soft to hard. In general, streamflow is less mineralized than ground water, particularly when it consists largely of direct runoff. However, streams become more highly mineralized during low-flow conditions, when most flow consists of more highly mineralized water discharged from aquifers. The median dissolved-solids concentration in water from 25 stream sites was 113 mg/L (milligrams per liter) during high flow, and 148 mg/L during low flow within the study period. Iron and manganese occur naturally in objectionable concentrations in some streams draining swamps and in some waters draining from sedimentary bedrock which contains iron- and manganese-bearing minerals.

Man's activities have affected the water quality of streams in much of the area, particularly in the Hockanum and Park River basins. The degradation in quality in these streams is shown by wide and erratic changes in dissolved-solids concentration, excessive amounts of trace elements, a low dissolved-oxygen content, and abnormally high temperatures. Ground water within this area is degraded principally by induced infiltration of surface water that contains chemical wastes, by leachate from wastes stored or disposed of on the ground, and by effluents discharged from septic tanks.

The quantity and quality of water are satisfactory for a wide variety of uses, and, with suitable treatment, the water may be used for most purposes. The total amount of water used in 1968 was more than 100 billion gallons. About 80 percent of this was used for industrial purposes, and 90 percent of the industrial water was obtained from surface-water sources. About 85 percent of the population was supplied with water for domestic use by 15 major public and municipal systems and 25 private associations. Analyses of water from the 13 largest systems show generally good quality.

INTRODUCTION

PURPOSE AND SCOPE

Connecticut has experienced a significant population increase within the past few decades accompanied by industrial growth, changes in land-use patterns, and an improved standard of living. These factors have contributed to a continuing increase in the demand for water. The total amount of water available in Connecticut is sufficient for immediate and anticipated needs, but its quantity and quality vary in place and time. Therefore, a need exists for accurate information to plan for the development of known supplies and to evaluate the potential water resources of undeveloped areas.

In 1959, the Connecticut General Assembly, on recommendation of the Water Resources Commission, authorized a statewide water-resources inventory. Under this and supplemental authorizations of the General Assembly, the U.S. Geological Survey, in cooperation with the Water Resources Commission (later incorporated with the Connecticut Department of Environmental Protection), has undertaken a series of studies to determine the quantity and quality of water available. For these investigations, Connecticut was divided into 10 study areas, each bounded by natural drainage divides, State boundaries, and Long Island Sound. (See map inside front cover.) The resulting reports are designed to be useful to planners, public officials, water-utility personnel, consulting hydrologists, well drillers, and others concerned with the development, management, use, conservation, and protection of water resources. This report describes one of the 10 study areas. A companion report (Ryder and Weiss, 1971) lists much of the hydrologic data on which this report is based. A list of cooperative reports on the water resources of other areas of Connecticut is given on the back cover of this report.

THE UPPER CONNECTICUT RIVER BASIN AREA

The term "upper Connecticut River basin", as used in this report, is a 508 square-mile area of the Connecticut River basin in north-central Connecticut, extending from the Massachusetts State line to the northern margin of the Mattabesset River basin at Middletown, and Wilcox Island on the Connecticut River. It does not include the Farmington River basin upstream from Tariffville. (See index map in back of front cover.)

The Connecticut River, the largest stream in New England, rises near the Canadian border and flows southward through Connecticut to Long Island Sound. (See figure 1.) The Connecticut part of the Connecticut River basin has been divided into three study areas; (1) the area shown in figure 1, known as the upper Connecticut, (2) the area to the south, called the lower Connecticut River basin, and (3) the Farmington River basin within Connecticut and upstream from Tariffville. The second and third areas are covered in separate reports.

Much of the basin is within the southern part of the Triassic and Jurassic valley, a broad central lowland containing prominent basalt ridges. The lowland is flanked by a ridge of moderate height on the west; the downstream end of the Farmington River basin is the point where the Farmington River penetrates the basalt ridge. To the east, the lowland is flanked by metamorphic crystalline rocks also of moderate height. Elevations range from mean sea level at Middletown, the outlet of the basin, to more than 1,000 feet above mean sea level on the margin. The land surface is generally flat or gently rolling, but steep escarpments and adjacent talus slopes characterize the west flanks of the larger basalt ridges.

The Connecticut River is the major stream; it has four large tributaries - the Scantic River, with a drainage area in Connecticut of 87 square miles; the Farmington River, with a drainage area downstream from Tariffville of 30 square miles; the Park River, with a drainage area of 76.2 square miles; and the Hockanum River, with a drainage area of 76.1 square miles. The complete drainage system is shown in figure 2 and also on the plates in the back pocket.

Land use includes large-scale industrial and commercial development in Hartford and the nearby towns of East Hartford and West Hartford near the center of the study area. Major industries include manufacturer of aircraft jet engines, firearms, mechanical counters, and machine tools. The Hartford area is the home office of many insurance companies and is nationally known as "The Insurance City". Farms and woodlands are common along the eastern and western margins; rural valley areas were intensively farmed with tobacco, but the central lowland is now becoming residential.

Transportation systems are well developed; three major highways, interstate routes 84, 86, and 91 serve the area. Rail services from New Haven to Hartford and north toward Springfield are part of the Amtrak and Conrail Systems, and spur lines serve several smaller towns.

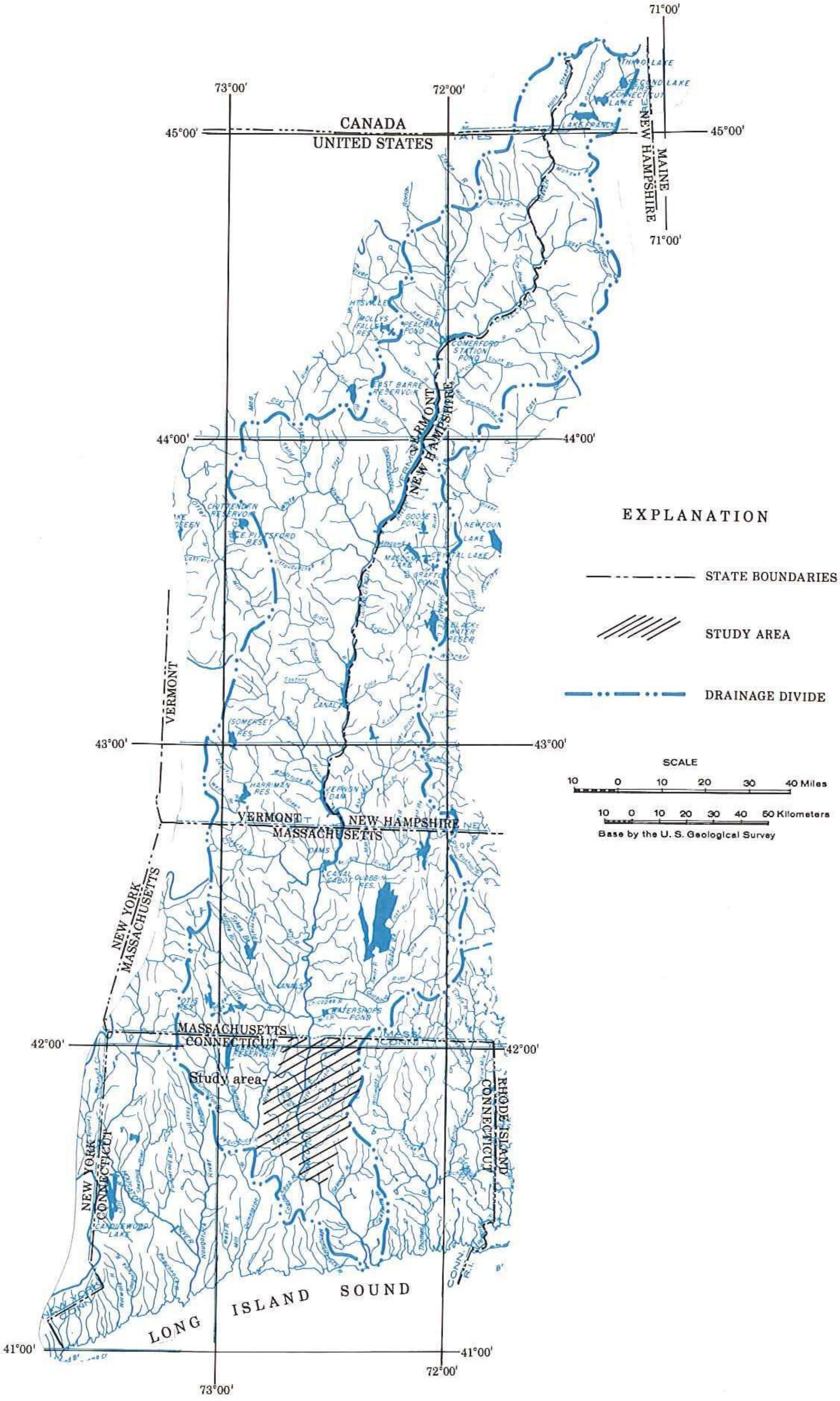


Figure 1.--Map showing the Connecticut River basin and the study area.

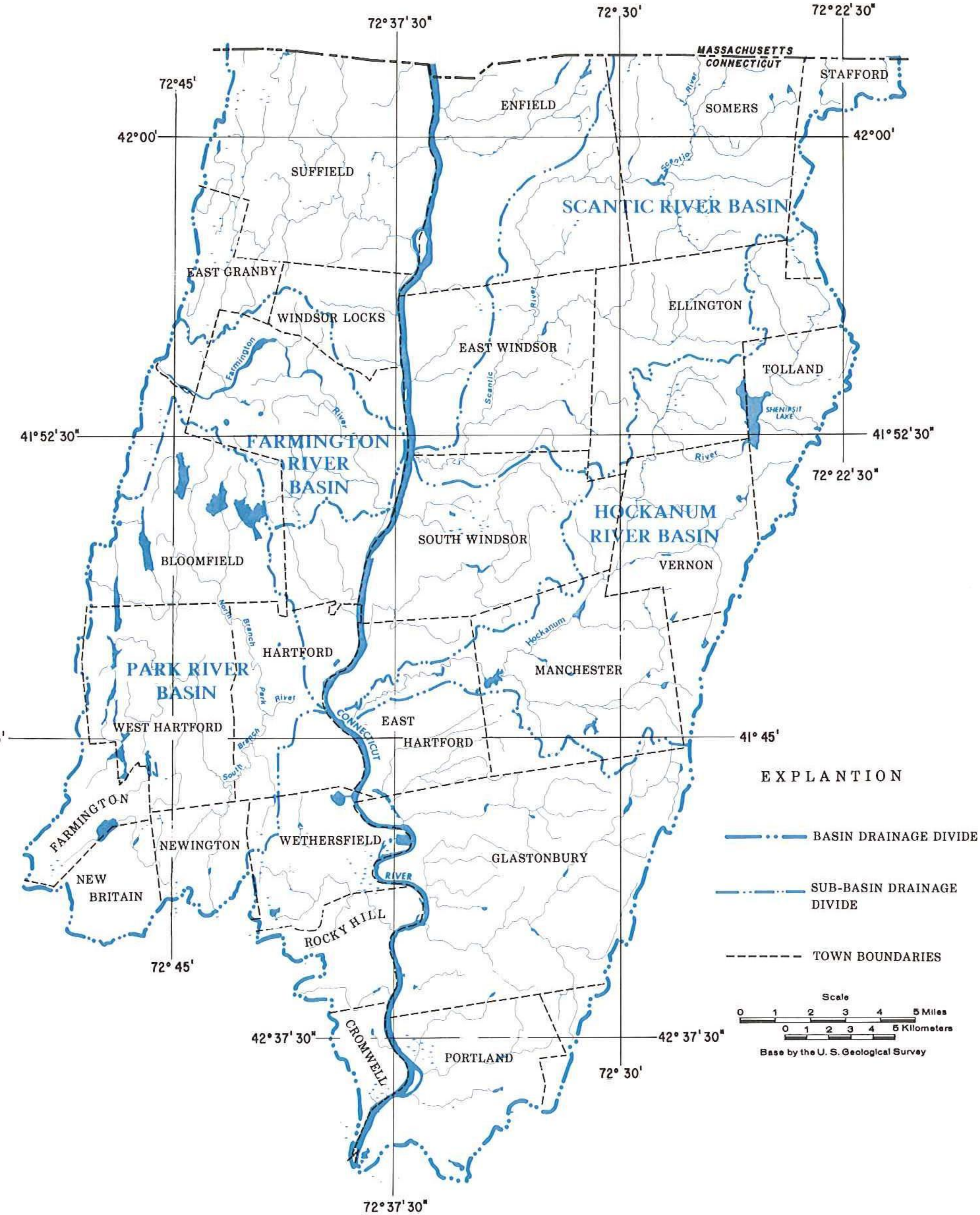


Figure 2.--Map showing drainage system and major streams in the upper Connecticut River basin.

GUIDE FOR THE USE OF THIS REPORT

Water supplies may be obtained from streams, lakes, and aquifers. Methods used to estimate the amount of water potentially available from each source and the techniques of development are sufficiently different to be treated in separate surface-water and ground-water sections of this report.

The availability of surface water is summarized on plate C-1, which shows the amount of usable storage of selected reservoirs and low flows of major streams. Streamflow information in the text includes tables and graphs of flow duration, low-flow frequency and duration, flood peaks, frequency of floods, and draft-storage relations. Quality of surface water is discussed in the text in the section titled "Quality of Water". Maximum dissolved-solids concentration in streams is shown in figure 27.

The availability of ground water is summarized on plates B and C-1. Plate B delineates the principal unconsolidated water-bearing units and the saturated thickness and composition of the stratified drift. The range in well yield of principal water-bearing units is given. Plate C-1 shows areas of stratified drift favorable for the development of large ground-water supplies. The text discusses the aquifers, the movement and storage of ground water, and the methods used to estimate the favorable areas. It includes data on yields for each of the main types of bedrock. The quality of ground water is discussed in the section titled "Ground-water Quality".

Water use is shown on plate D and discussed in the text. Table 23 lists water-quality data for the principal public water-supply systems and figure 41 is a general illustration of water collection, use, and disposal.

All data collection points referred to in this report are located on plate A, which was previously published in the companion hydrologic-data report (Ryder and Weiss, 1971). The hydrologic-data report also contains well records, logs of wells and test holes, records of pumping tests, chemical analyses and physical characteristics of water from wells and streams, and sources of other published hydrologic and water-quality information.

A list of abbreviations, some common equivalent relations, and a glossary of technical terms are included at the end of this report.

ACKNOWLEDGMENTS

The data on which this report is based were collected and analyzed by employees of the U.S. Geological Survey. Unpublished information was obtained from the files of several State agencies, including the Departments of Environmental Protection, Transportation, Economic Development, and the Office of Policy and Management.

Ground-water data from Geraghty & Miller Inc., consulting ground-water geologists, and well and test-hole data from the S. B. Church Co. and the R. E. Chapman Co. contributed significantly to the study. Other information and assistance was provided by property owners, well drilling contractors, consultants, planning agencies, and company and public officials too numerous to name. All have helped to make this report possible; their contributions are sincerely appreciated.

THE HYDROLOGIC CYCLE

The hydrologic cycle is a term used to denote the circulation of water between oceans, land masses, and the atmosphere. When water vapor in the atmosphere condenses to form clouds, rain or snow often falls onto the land surface. Part of this water flows across the land to collect in streams and lakes, and part seeps into the ground. Much of the water on the land surface or in the ground is soon evaporated or taken up by plants and returned to the atmosphere by transpiration. Some, however, moves through permeable soils and rocks and discharges into nearby streams. The part that reaches the streams, lakes, and eventually the oceans, is evaporated to complete the cycle.

As water moves through the hydrologic cycle, large amounts are stored temporarily in the atmosphere as vapor or clouds, on the land surface in streams and lakes, and beneath the land surface as ground water. The amounts of storage change continuously as the water moves and, at the same time, the physical, chemical, and biological properties of the water also change. These changes are described in subsequent sections.

THE WATER BUDGET

In a specific drainage basin, the hydrologic cycle can be described by a water budget, which, like a fiscal budget, lists receipts, disbursements, and amounts on hand. The receipts of water in the upper Connecticut River basin consist of precipitation on the area, inflow of the Connecticut River and Scantic River at the Massachusetts line, inflow of the Farmington River at Tariffville, diversion from the Farmington River basin for Hartford water supply (the Farmington River basin is covered in a separate report), and inflow from many other small streams entering from Massachusetts. Disbursements consist of surface runoff, ground-water runoff, and evapotranspiration. The amount on hand - stored within the basin - is continuously changing. The amounts in each element of the budget may vary from year to year, but the budget always balances. The approximate amounts involved in each of the major elements of the water budget in an average year are shown in figure 3.

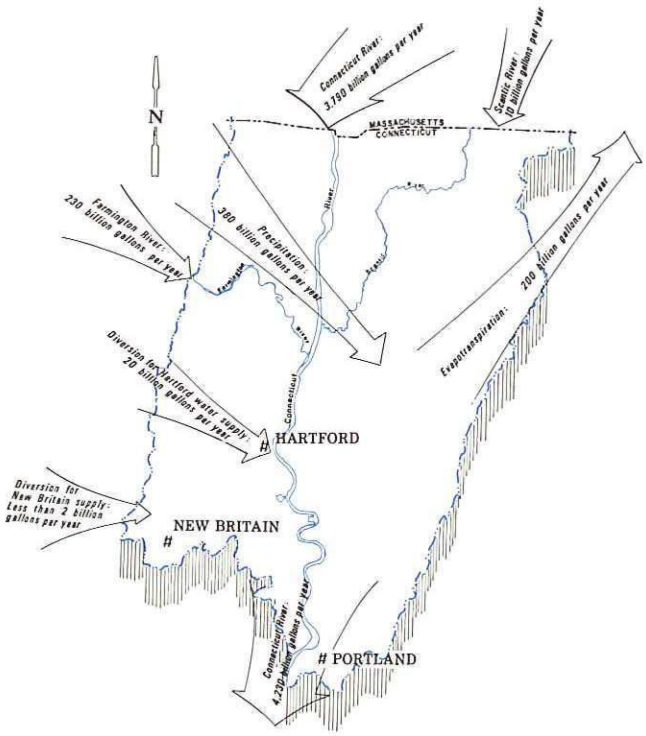


Figure 3.--Map showing the annual water budget for the upper Connecticut River basin.

Average figures, based on water years 1931-60, in billion gallons per year.

SOURCES OF WATER

PRECIPITATION

The mean-monthly and mean-annual precipitation on the upper Connecticut River basin for the reference period, October 1930 to September 1960, is shown by records for Hartford, which is near the center of the study area. Figure 4 and table 1 show that the mean precipitation for each month is fairly uniform, ranging from 2.97 inches in February to 4.16 inches in November; the average is 3.69 inches. Minimum monthly precipitation for the period of record ranges from 0.63 inches (September 1948) to 1.84 inches (March 1946). Maximum monthly precipitation ranges from 5.27 inches (February 1960) to 21.87 inches (August 1955).

STREAMFLOW, UNDERFLOW, AND DIVERSION INTO THE REPORT AREA

Precipitation is the only natural source of water for all stream basins that are entirely within the report area. However, a substantial

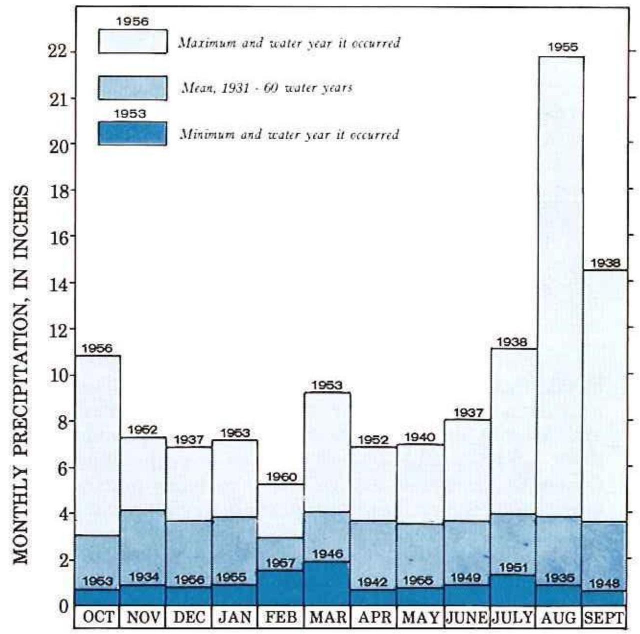


Figure 4.--Graph showing monthly precipitation, at Hartford, 1931-60 water years.

Mean precipitation for each month is fairly uniform; maximum and minimum precipitation vary widely.

resource is streamflow entering from Massachusetts in the Connecticut and Scantic Rivers and in the Farmington River at Tariffville. The average inflow from Massachusetts in the first two rivers totals about 3,800 billion gallons per year, and that from the Farmington River is about 230 billion gallons per year. The inflow-outflow pattern of streamflow is shown in figure 3.

A negligible amount of underflow enters through fine-grained sediments at the Massachu-

Table 1.--Water budget of the upper Connecticut River basin.

(Mean monthly budget, 1931-60 water years, in inches of water)

Month	Precipitation	Evapotranspiration	Precipitation minus evapotranspiration	Runoff	Storage 1/
Oct.	3.03	1.66	1.37	1.03	0.34
Nov.	4.16	.67	3.49	1.63	1.86
Dec.	3.70	2/ .20	3.50	1.99	1.51
Jan.	3.80	2/ .20	3.60	2.23	1.37
Feb.	2.97	2/ .20	2.77	2.14	.63
Mar.	4.02	.38	3.64	3.60	.04
Apr.	3.72	1.51	2.21	3.15	- .94
May	3.57	2.83	.74	2.05	-1.31
June	3.66	3.75	- .09	1.34	-1.43
July	4.00	4.31	- .31	.88	-1.19
Aug.	3.86	3.82	.04	.91	- .87
Sept.	3.68	2.68	1.00	1.01	- .01
Mean annual	44.17	22.21	21.96	21.96	0

1/ Minus sign indicates net loss in storage; no sign indicates net gain.

2/ Estimated for times when air temperature was above freezing; assumed to be zero when air temperature was at or below freezing.

setts line because the hydraulic gradient is small and the unconsolidated materials are only slightly permeable.

Water is diverted into the area from the Farmington River basin for municipal supply of the Hartford metropolitan area. Long-term records indicate that this diversion averages about 20 billion gallons per year.

LOSSES OF WATER

RUNOFF

Runoff from the upper Connecticut River basin has been measured in the Scantic River at Broad Brook, in the Park River at Hartford, and in the Hockanum River near East Hartford. Mean monthly and annual values for the upper Connecticut River basin for the base period, October 1930 to September 1960, are shown in figure 5 and in table 1. Figure 5 shows that the mean-monthly runoff follows a marked seasonal cycle; it is much lower in July (0.88 inch) than in March (3.60 inches). Minimum monthly values likewise indicate the same seasonal cycle. This reflects a combination of causes, among which are increased evaporation and transpiration during the summer; storage of water as ice and snow during the winter, and increased ground-water runoff in the spring. Maximum-monthly runoff varies widely but does not show a seasonal cycle because large floods can occur in any month.

STREAMFLOW AND UNDERFLOW OUT OF THE REPORT AREA

The average annual streamflow leaving the report area is about 4,230 billion gallons. Underflow is negligible. The inflow-outflow pattern of streamflow is shown in detail in figure 3.

EVAPOTRANSPIRATION

Much of the precipitation on the basin is returned to the atmosphere by evaporation and transpiration. The combined process, evapotranspiration, is difficult to measure directly and is commonly computed as a remainder after all other gains and losses have been accounted for. Measurements of reservoir and ground-water levels indicate that surface-water storage does not change substantially over long periods. Therefore, mean annual evapotranspiration is estimated to be equal to mean annual precipitation (44.17 inches) minus mean annual runoff (21.96 inches), or 22.21 inches.

Evapotranspiration rates change throughout the year in response to changes in air temperature and duration of daylight (Thornthwaite, 1952, p. 382). They are highest during the growing season, April through October, when the temperature is high and daylight hours are increased. The cycle repeats itself with little change year after year, and annual evapotranspiration is relatively constant for a given locality. Theoretical mean-monthly

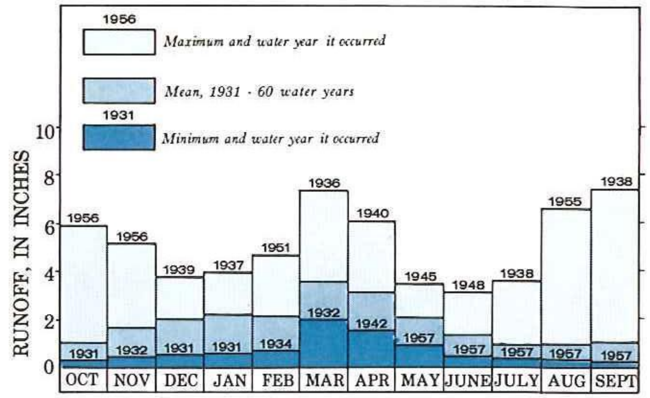


Figure 5.--Graph showing monthly runoff for the upper Connecticut River basin, 1931-60 water years.

Mean-monthly and minimum-monthly runoff follow a seasonal cycle; maximum-monthly runoff can vary widely as a result of floods which may occur in any month of the year.

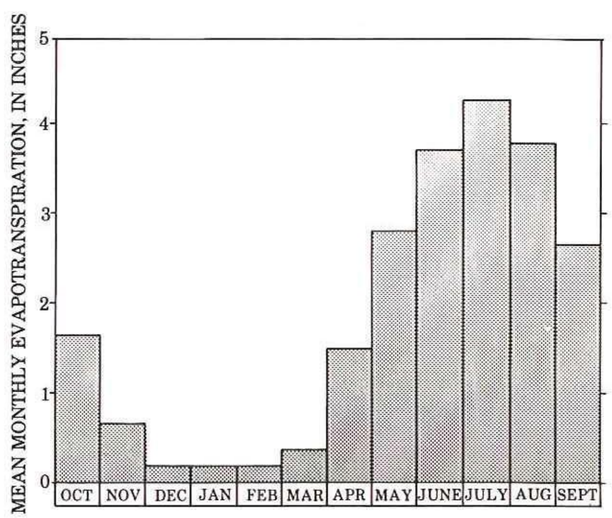


Figure 6.--Graph showing mean monthly evapotranspiration, for the upper Connecticut River basin, 1931-60 water years.

evapotranspiration rates are computed by a method similar to that described by Thornthwaite and Mather (1957) and are shown in figure 6 and in table 1.

SUMMARY OF THE WATER BUDGET

A mean monthly budget for the project area is shown in figure 7 and table 1. Precipitation in late autumn and winter exceeds evapotranspiration, which results in increased storage and abundant runoff. Precipitation in late spring and summer is generally less than evapotranspiration; this results in decreased storage and sharply reduced runoff. Storage of water thereby changes in lakes, stream channels, aquifers, and soils.

Table 2.--Streamflow records at gaging stations in the upper Connecticut River basin.

(Data through 1978 water year)

Station no. (pl. A)	Stream and place of measurement	Drainage area (mi^2)	Type of record	Period of record, in water years
01183950	Grape Brook at Thompsonville	2.52	Low flow	1963-67
			Continuous	1968-69
01183980	Freshwater Brook near Hazardville	4.34	Low flow	1963-73
01183990	Jawbuck Brook near Hazardville	2.16	Low flow	1963-76
			Peak flow	1967-76
01184000	Connecticut River at Thompsonville	9,661	Continuous	1928-78
01184100	Stony Brook near West Suffield	10.2	Low flow	1960-78
			Peak flow	1961-78
01184205	Muddy Brook near Suffield	11.4	Low flow	1963-67
			Continuous	1968-69
01184208	Philo Brook near Suffield	4.20	Low flow	1963-73
01184210	Clay Brook at Suffield	.75	Low flow	1963-73
01184250	Kettle Brook at Windsor Locks	1.63	Low flow	1963-67
			Continuous	1968-69
01184260	Namerick Brook near Warehouse Point	2.70	Low flow	1963-78
			Peak flow	1964-78
01184280	Scantic River at North Somers	26.7	Low flow	1963-66
			Continuous	1967-69
01184290	Watchaug Brook near North Somers	8.55	Low flow	1963-73
01184300	Gillette Brook at Somers	3.64	Low flow	1960-67
			Peak flow	1961-67
			Continuous	1968-69
			Low flow	1970-78
			Peak flow	1970-78
01184400	Buckhorn Brook near Melrose	4.36	Low flow	1961-73
01184450	Broad Brook at Ellington	5.72	Low flow	1963-73
01184490	Broad Brook at Broad Brook	15.6	Continuous	1961-76
01184500	Scantic River at Broad Brook	98.2	Continuous	1928-71
			Low flow	1972-78
			Peak flow	1972-78
01189995	Farmington River at Tariffville	577	Peak flow	1913-28
			Continuous	1929-39
01190000	Farmington River at Rainbow	589	Continuous	1940-78
01190002	Hathaway Hollow Brook at Poquonock	.64	Low flow	1967-68
01190020	Mill Brook at Windsor	6.07	Low flow	1963-65
			Continuous	1967-68
01190030	Meadow Brook at Wilson	3.15	Low flow	1963-73
01190050	Podunk River at Wapping	4.34	Low flow	1961-76
			Peak flow	1962-76
01190100	Piper Brook at Newington Junction	14.6	Continuous	1958-71
			Low flow	1972-78
			Peak flow	1972-78
01190200	Mill Brook at Newington	2.65	Continuous	1958-71
			Low flow	1972-78
			Peak flow	1972-78
01190300	Trout Brook at West Hartford	14.6	Continuous	1958-71
01190500	South Branch Park River at Hartford	39.9	Continuous	1937-78
01190600	Wash Brook at Bloomfield	5.54	Continuous	1958-71
01190620	Tumbledown Brook near Bloomfield	6.97	Continuous	1967-68
01190650	Beamans Brook at Bloomfield	4.58	Low flow	1963-65
			Continuous	1968-69
01191000	North Branch Park River at Hartford	25.1	Continuous	1937-78
01191500	Park River at Hartford	73.0	Continuous	1937-62
01191900	Charter Brook near Crystal Lake	8.51	Low flow	1961-78
			Peak flow	1965-78
01192200	Tankerhoosen River at Vernon Center	9.19	Low flow	1967-68
01192500	Hockanum River near East Hartford	73.4	Continuous	1919-21
				1928-71
			Peak flow	1972-76
			Continuous	1977-78
01192560	Porter Brook near East Hartford	4.94	Partial	1967-68
01192600	South Branch Salmon Brook at Buckingham	.94	Continuous	1961-76
01192610	Salmon Brook at Glastonbury	7.93	Continuous	1967-68
01192640	Cold Brook near East Glastonbury	5.81	Low flow	1967-73
01192650	Roaring Brook at Hopewell	24.3	Continuous	1962-71
			Low flow	1972-75
			Peak flow	1972-76
01192670	Goff Brook near South Wethersfield	5.13	Low flow	1963-73

SURFACE WATER

STREAMS

This report describes an area of 508 square miles of the Connecticut River basin in Connecticut, extending southward from the Massachusetts State line to the northern margin of the Mattabesset River at Middletown; it does not include the Farmington River basin upstream from Tariffville. (See index map on back of front cover.) This part of the basin is drained by four major stream systems: the Scantic River, with a drainage area in Connecticut of 87 square miles (27 square miles in Massachusetts); the Farmington River, with a drainage area downstream from Tariffville of 30 square miles; the Park River, with a drainage area of 76.2 square miles; and the Hockanum River, with a drainage area of 76.1 square miles. The complete drainage system is shown in figure 2 and also on the plates in the back pocket.

Separate reports cover the Farmington River basin in Connecticut upstream from Tariffville and the lower Connecticut River basin extending from the northern margin of the Mattabesset River to Long Island Sound.

The amount of streamflow passing any point on a stream varies continuously. Continuous and partial records of flow have been collected at 41 sites for up to 47 years and at 25 of these sites for 10 years or more. The sites are shown on plate A, and the years of record are listed in table 2. These records have been published annually from 1928 through September 1970 by the U.S. Geological Survey in a series of Water Supply Papers titled "Surface Water Supply of the United States." They were also published from October 1960 to September 1964 as "Surface Water Records of Connecticut" and since October 1964 as "Water Resources Data for Connecticut". All of these publications are listed under "U.S. Geological Survey" in the "References" at the back of this report.

Streamflow records are the basis for the determination of water-supply potential and are used to estimate mean annual flow, duration of flows, frequency and duration of low and high flows, and magnitude and frequency of floods. All records except flood records are extended or shortened to the 30-year reference period, 1930-60, beginning in April or October 1930, so that comparable estimates may be made for any selected location. This reference period conforms with the practice agreed upon by the World Meteorological Organization (Searcy, 1959) and is consistent with previous reports in this series. Duration of flow and frequency and duration of low flow for each 30-year record are further adjusted to an average mean annual streamflow of 1.16 million gallons per day per square mile (1.80 cubic feet per second per square mile) for the 30-year reference period for the State as a whole.

Regional relationships may be applied to any site on any stream provided that no diversion, regulation, or significant urban development exists upstream from the site. They can also be applied to that part of a drainage area downstream from a point of diversion. If the amount and time distribution are known at a point of partial diversion, appropriate adjustment to the regional relationship may be made. Regulation, if known, can also be adjusted for.

The "Gazetteer of Natural Drainage Areas of Streams and Water Bodies within the State of Connecticut" (Thomas, 1972) lists the sizes of drainage areas at specific sites, and maps showing the drainage area delineations on which that report is based are available for reference in the Hartford office of the U.S. Geological Survey.

MEAN ANNUAL STREAMFLOW

The amount of flow passing a point on a stream at any time depends upon the size of the upstream drainage area, precipitation, evapotranspiration, surface-water and ground-

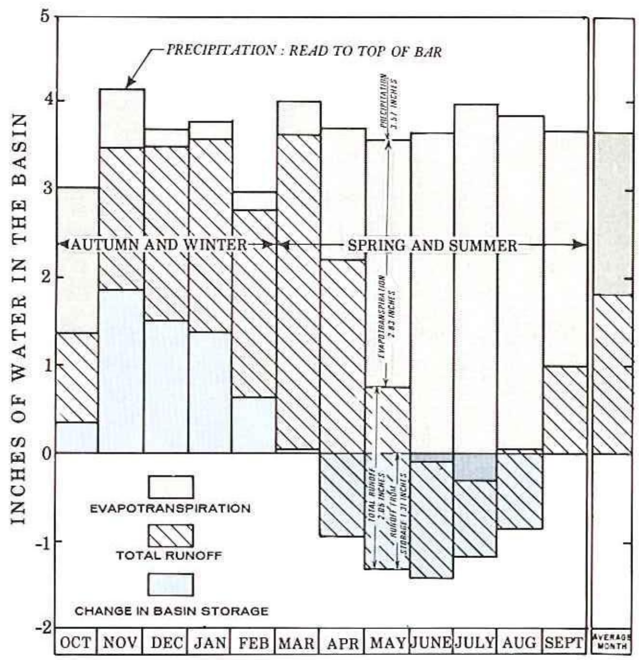


Figure 7.--Graph showing mean monthly water budget for the upper Connecticut River basin, 1931-60 water years.

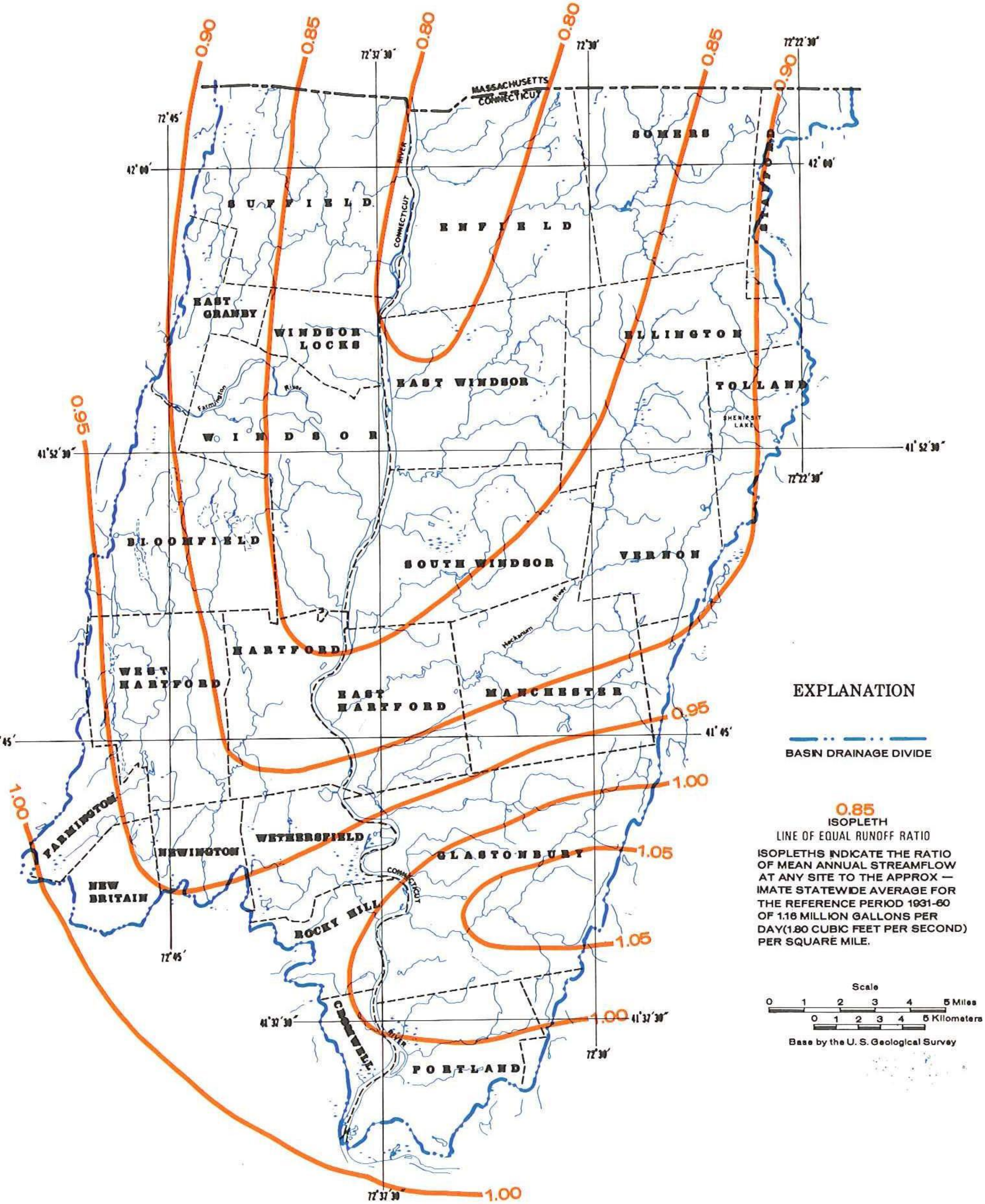


Figure 8.--Map showing distribution of ratios of local mean annual streamflow to the statewide mean in the upper Connecticut River basin, 1931-60 water years.

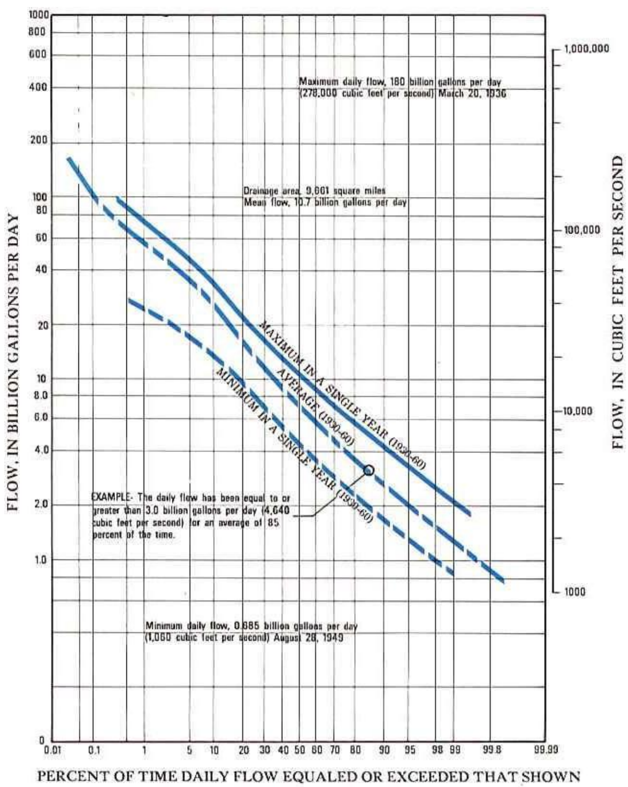


Figure 9.--Flow duration curve of the Connecticut River at Thompsonville.

Duration of daily mean streamflows, Station No. 01184000, without adjustment for regulation and diversion.

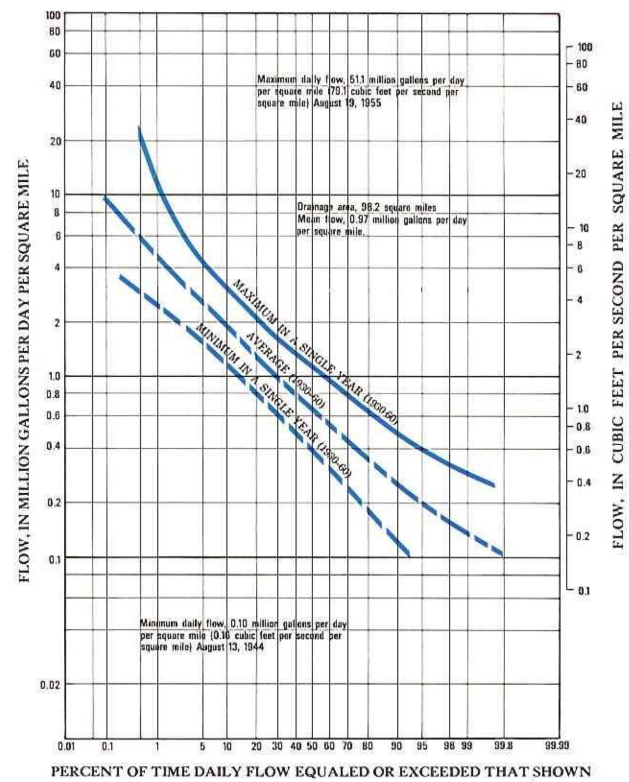
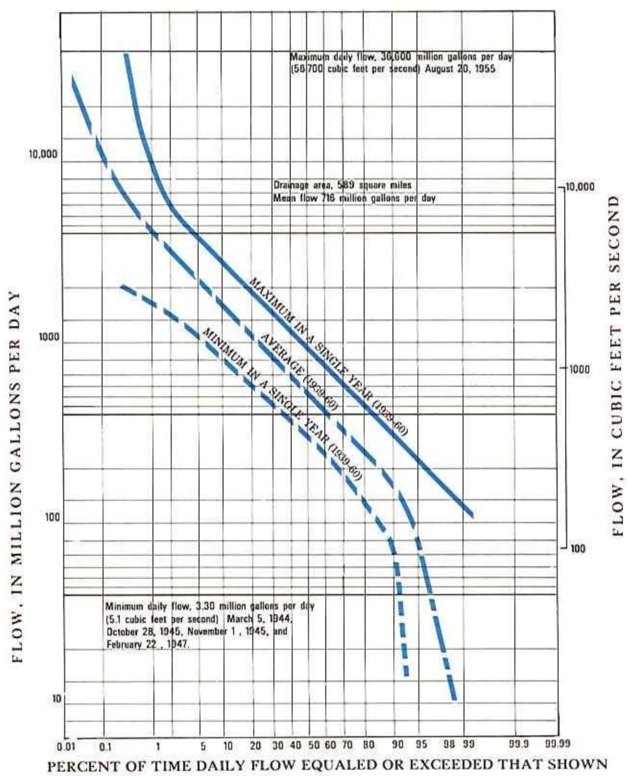


Figure 10.--Flow duration curve of the Scantic River at Broad Brook.

Duration of daily mean streamflows, Station No. 01184500.



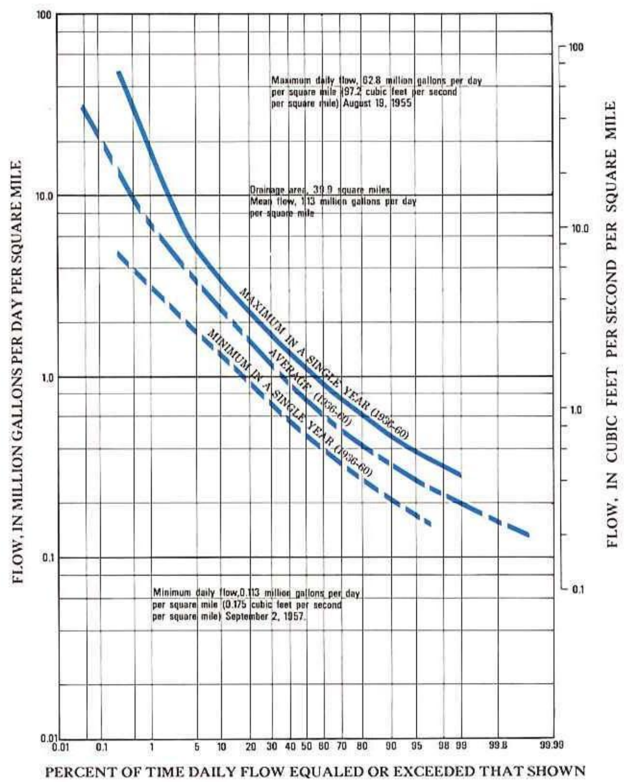


Figure 11.--Flow duration curve of the Farmington River at Rainbow.

Duration of daily mean streamflows, Station No. 01190000, without adjustment for regulation and diversion.

Figure 12.--Flow duration curve of the South Branch Park River at Hartford.

Duration of daily mean streamflows, Station No. 01190500, without adjustment for regulation and diversion.

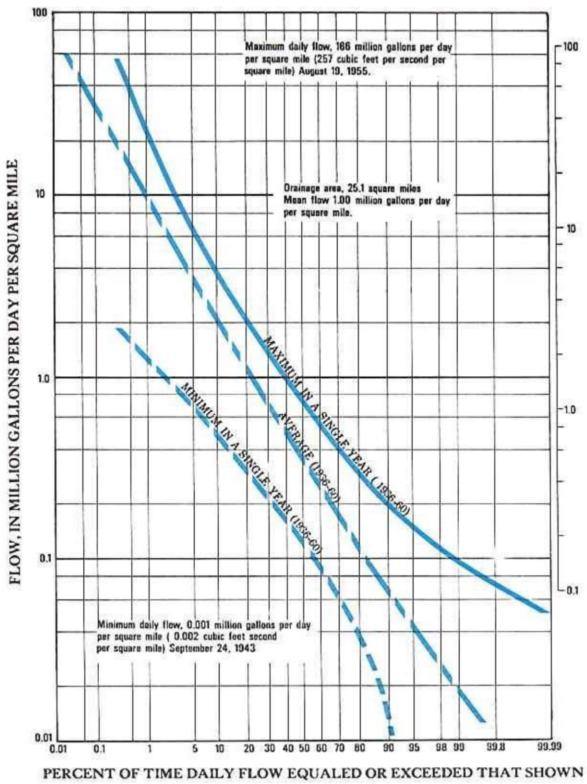


Figure 13.--Flow duration curve of the North Branch Park River at Hartford.

Duration of daily mean streamflow, Station No. 01191000.

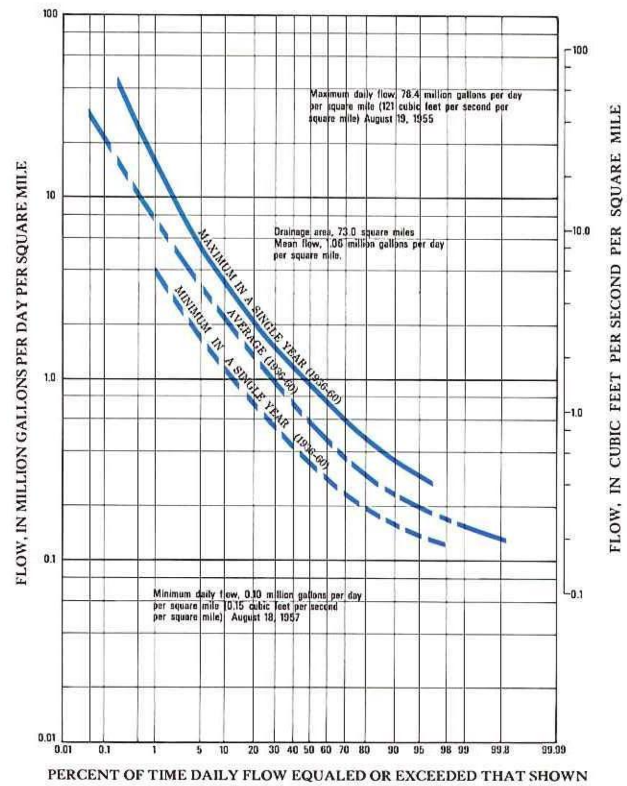


Figure 14.--Flow duration curve of the Park River at Hartford.

Duration of daily mean streamflows, Station No. 01191500, without adjustment for regulation and diversion.

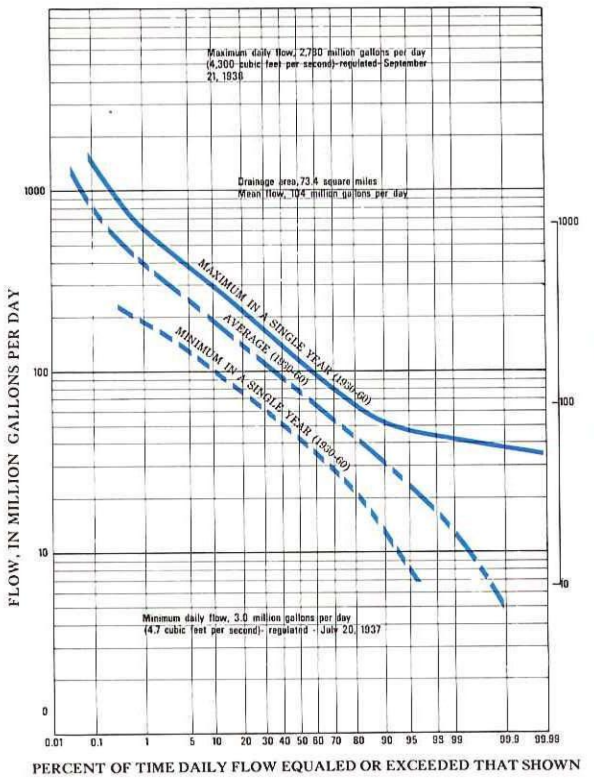


Figure 15.--Flow duration curve of the Hockanum River at East Hartford.

Duration of daily mean streamflows, Station No. 01192500, without adjustment for regulation and diversion.

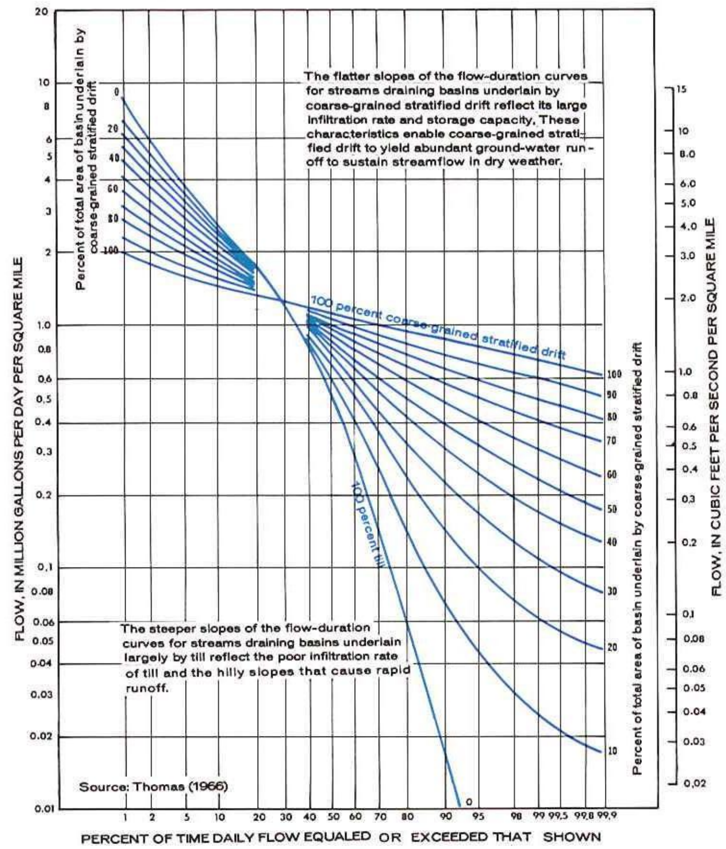


Figure 16.--Graph showing the relation of the duration of daily mean flow to percent of coarse-grained stratified drift underlying the drainage area.

Based on average for 1931-60 water years. Curves apply to unregulated streams having a mean annual flow of 1.16 $(Mgal/d)/mi^2$ [$1.80\ (ft^3/sec)/mi^2$].

water storage, topography, and the influence of man on the system. The areal variation in the mean annual streamflow of unregulated streams is shown by the lines of equal ratio in figure 8. These lines connect all points having the same ratio of local mean annual streamflow to the statewide average mean annual streamflow of 1.16 million gallons per day per square mile (1.80 cubic feet per second per square mile) for the reference period, 1930-60. To determine the amount of streamflow at a specific site on a stream, use a weighted average ratio representative of the entire upstream drainage area.

DURATION OF STREAMFLOW

Cumulative frequency curves, called flow-duration curves, show the average percentage of time specific daily flows are equaled or exceeded at sites where continuous records of daily flow are available. Flow-duration curves based on continuous records from stream-gaging stations in the study area for the reference period, 1930-60, are shown in figures 9 to 15. Also shown are the minimum and maximum limits of duration in a single year.

A family of regional flow-duration curves developed by Thomas (1966) for ungaged sites shows the effect of basin surficial geology on flow duration. Regional flow-duration curves, based upon statewide data, are shown in figure 16. In general, the curves show that streamflow from areas having a large proportion of coarse-grained stratified drift is more evenly distributed in time than streamflow from areas of till-mantled bedrock. This reflects the generally large infiltration rate and storage capacity of coarse-grained stratified drift and the resultant high proportion of ground-water runoff from these deposits. In contrast, the uneven time distribution of streamflow from till-bedrock areas reflects the poor infiltration rate and low storage capacity of these deposits and the resultant large proportion of surface runoff.

Some drainage basins are predominantly underlain by fine-grained stratified drift (clay, silt, and very fine sand) in sites of former glacial lakes. These sediments, like till, have a relatively low infiltration rate, and most runoff is overland to streams. Flow-duration curves for streams draining these

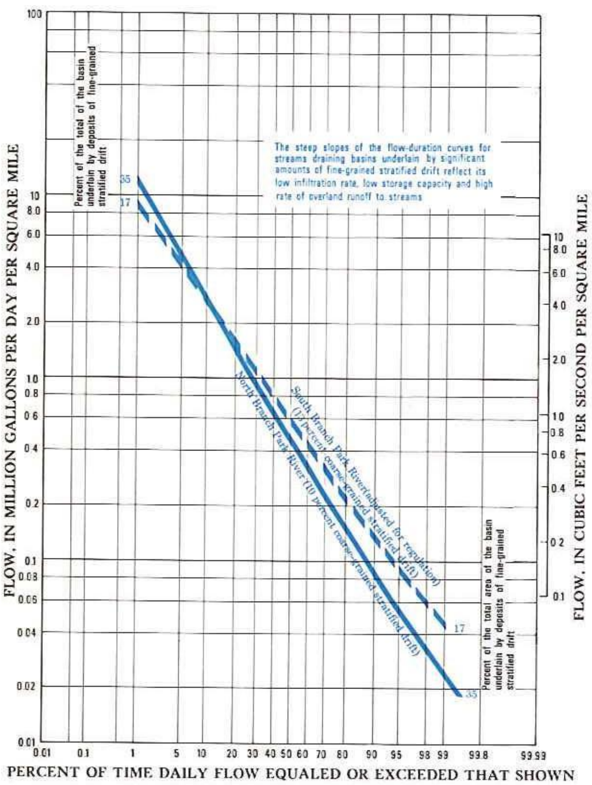


Figure 17.--Graph showing the duration curves of daily mean streamflow for two stream basins underlain by significant amounts of fine-grained stratified drift, 1931-60 water years.

In general, duration curves for basins underlain by significant percentages of fine-grained stratified drift are steeper and more similar to curves for basins underlain largely by till, as shown in figure 16.

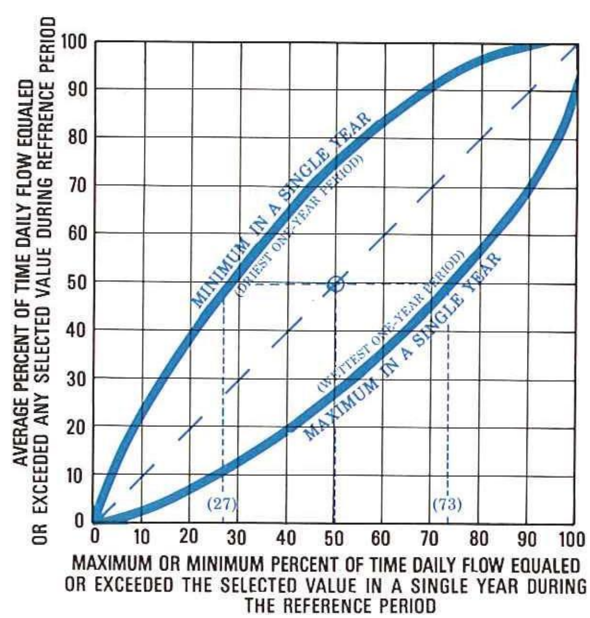


Figure 18.--Graph showing the range in duration of streamflow in the upper Connecticut River basin, 1931-60 water years.

Table 3.--Annual lowest mean flows for different periods and recurrence intervals

(Flows measured at long-term stream-gaging stations in the upper Connecticut River basin and adjusted to the reference period 1931-60)

Station no. (pl. A)	Stream and place of measurement	Drainage area (mi^2)	Period of low flow (consecutive days)	Annual lowest mean flow (ft^3/s) for indicated recurrence interval (years) 1.2	2	3	5	10	20	31	Annual lowest mean flow [(Mgal/d)/mi^2] for indicated recurrence interval (years) 1.2	2	3	5	10	20	31
01184500	Scantic	98.2	3	40	28	25	22	20	18	17	.265	.187	.162	.142	.129	.116	.110
	River		7	43	31	28	25	22	20	19	.284	.207	.181	.162	.142	.129	.123
	at		30	54	40	35	31	28	25	23	.355	.265	.233	.207	.181	.162	.149
	Broad		60	63	46	41	35	31	28	26	.414	.304	.271	.233	.207	.187	.174
	Brook		120	82	60	51	43	37	33	30	.536	.394	.336	.284	.246	.220	.200
			183	103	75	63	53	44	39	36	.679	.491	.414	.349	.291	.258	.239
			274	138	98	81	69	57	51	47	.905	.646	.530	.452	.375	.336	.309
			365	172	123	100	87	73	66	61	1.13	.808	.659	.569	.478	.433	.401
01190500	South	39.9	3	22	15	13	11	9.74	8.93	8.12	.291	.233	.207	.174	.155	.142	.129
	Branch		7	24	16	14	12	10	9.74	8.93	.323	.252	.226	.194	.168	.155	.142
	Park		30	35	19	17	15	12	11	10	.414	.304	.271	.233	.200	.181	.168
	River		60	46	22	19	16	14	12	12	.491	.349	.304	.258	.220	.200	.187
	at		120	64	28	24	21	18	16	15	.646	.446	.388	.336	.291	.258	.246
	Hartford		183	84	35	30	26	23	21	19	.840	.556	.478	.420	.362	.330	.304
			274	114	48	41	35	30	28	26	1.13	.756	.646	.562	.485	.446	.420
			365	150	64	55	49	42	38	36	1.49	1.01	.872	.776	.666	.614	.569
01191000	North	25.1	3	1.97	1.04	.708	.473	.286	.174	.129	.050	.026	.018	.012	.007	.004	.003
	Branch		7	2.50	1.34	.911	.620	.377	.228	.172	.064	.034	.023	.016	.010	.006	.004
	Park		30	4.28	2.30	1.57	1.12	.653	.384	.296	.109	.059	.040	.028	.017	.010	.008
	River		60	6.32	3.26	2.23	1.47	.873	.526	.405	.162	.083	.057	.037	.022	.013	.010
	at		120	12	5.64	3.74	2.40	1.39	.822	.589	.317	.144	.096	.061	.036	.021	.015
	Hartford		183	20	9.36	5.94	3.97	2.25	1.24	.860	.517	.239	.152	.101	.058	.032	.022
			274	35	17	12	7.84	4.55	2.48	1.64	.892	.439	.310	.200	.116	.063	.042
			365	57	30	22	15	8.35	5.57	3.80	1.45	.776	.549	.375	.213	.142	.097
01191500	Park	72.5	3	24	18	16	13	11	8.88	8.14	.213	.162	.142	.116	.097	.078	.071
	River		7	27	21	18	15	12	9.62	8.88	.233	.181	.155	.129	.103	.084	.078
	at		30	35	26	22	18	15	12	11	.304	.226	.194	.162	.129	.103	.097
	Hartford		60	43	31	26	22	18	14	12	.375	.271	.226	.194	.155	.123	.110
			120	59	41	33	28	22	18	16	.517	.355	.291	.246	.194	.162	.142
			183	81	53	44	36	30	24	21	.711	.465	.381	.317	.258	.213	.187
			274	118	74	61	52	42	35	31	1.03	.646	.530	.452	.368	.304	.271
			365	166	100	81	68	58	48	44	1.45	.872	.711	.592	.510	.420	.381

areas, based on data for the North and South Branches of the Park River, the only continuous records available, and adjusted to the statewide average for the reference period 1930-60, are shown in figure 17. Plate B delineates separately areas of coarse-grained and fine-grained stratified drift and also shows where coarse-grained stratified drift is overlain by fine-grained drift.

The flow-duration curves in figures 16 and 17 apply only to unregulated streams with mean annual streamflow of 1.16 (Mgal/d)/mi^2 (1.80 (ft^3)/s/mi^2), the statewide average for the reference period of 1930-60. They may be used in conjunction with figure 8 and the diagram in figure 18 to estimate flow-duration curves for ungaged sites on unregulated streams. For example, assume that an average flow-duration curve or table is needed for the period 1930-60 for a site with a drainage area of 10 square miles, of which 2.0 square miles, or 20 percent of the total, consists of coarse-grained stratified drift. The site is located where the mean annual streamflow for the upstream drainage area (from figure 8) is 0.90 times the statewide average. The flow-duration curve for this site is shown in figure 16 for 20-percent coarse-grained stratified drift. Values of flow from this curve must be multiplied by the drainage area, 10 square miles, and by the ratio, 0.90, to give the average flow-duration curve for this site for the period 1930-60. The result in tabular form is:

Percent of time	1	5	10	30	50	70	90	95	99
Average flow equaled or exceeded (Mgal/d)	58	31	15	11	7.2	3.8	1.7	1.2	0.7

Maximum and minimum flow-duration curves for a single year are estimated by relationships shown in figure 18. For example, if the flow of 7.2 Mgal/d was equaled or exceeded 50 percent of the time on the average flow-duration curve shown in the table above, then during the driest water year of the period 1931-60, this flow was probably equaled or exceeded 27 percent of the time, and, during the wettest year, 73 percent of the time. Any diversion or regulation upstream from a selected site requires adjustments to the natural flow-duration curve to account for its influence.

FREQUENCY AND DURATION OF LOW STREAMFLOW

Flow-duration curves indicate the percentage of time a daily low streamflow is equaled or exceeded during a certain period, but do not indicate how often this low flow recurs or how long it will last. These parameters are shown by curves of annual lowest mean flows for various periods of consecutive days and their recurrence intervals that are derived from long-term stream-gaging records. Annual lowest mean flows for various recurrence intervals are available for long-term stream-gaging stations (table 3). For short-term gaging stations and ungaged sites, relations between curves of lowest mean flow and flow-duration curves are shown in table 4. If flow-duration curves are known or estimated for such sites, low-flow frequency curves can be estimated by use of table 4. Commonly used indices of lowest mean flow are the lowest mean flow for 30 consecutive days with an average recurrence interval of 2 years (30-day, 2-year low flow), which is equivalent to the flow equaled or exceeded 90 percent of the time, and the lowest mean flow for 7 consecutive days with an average recurrence interval of 10 years (7-day, 10-year low flow), which is equivalent to the flow equaled or exceeded 99 percent of the time. The 30-day, 2-year low flow is shown on plate C-1 as an index of surface-water availability for this report. The State of Connecticut and its Department of Environmental Protection, in their report on criteria for water-quality standards (Connecticut General Assembly 1967, Public Act No. 57), recommend that the streamflow to which these standards apply be the 7-day, 10-year low flow.

The lowest mean flows not exceeded during periods of 7, 15, 30, 60, and 120 consecutive days at long-term gaging stations in the basin during the period April 1930 to March 1960, are given in table 5. No single climatic year contained all of the lowest flows, but the majority occurred between April 1957 and March 1958, and it can reasonably be assumed that most of the lowest flows throughout the basin occurred within this period.

Table 4.--Average duration of lowest mean flows of streams in Connecticut

Example shows that for any unmeasured site on an unregulated stream, the 30-consecutive-day low flow that could be expected to recur on the average every 2 years is equivalent to the flow equaled or exceeded 90 percent of the time.

Period of low flow	Average precent of time in which streamflow equaled or exceeded the lowest mean flow for indicated recurrence interval in years[1/]						
Consecutive days	1.2	2 median year	3	5	10	20	31 driest year
3	92	97	98	99.2	99.7	99.8	99.9
7	88	95	97	98	99.2	99.6	99.7
30	81	90	94	96	98	99	99.3
60	74	85	90	94	96	98	98
120	61	75	81	87	92	95	96
183	49	65	72	77	84	88	91
274	35	50	57	63	70	75	78
365	25	37	44	50	56	62	65

1/ Based on records from April 1930 to March 1960 at 34 continuous-record gaging stations throughout Connecticut.

STORAGE OF WATER

LAKES, PONDS, AND RESERVOIRS

Table 6 presents storage information relative to major surface-water bodies. The volume of usable water in storage that may be withdrawn by gravity through a valve or gate is shown as usable storage in table 6 and plate C-1. Table 7 shows maximum safe draft rates from lakes and reservoirs. Additional information on the public water-supply reservoirs is given in table 22.

ESTIMATING THE AMOUNT OF STORAGE NEEDED

If the minimum flow of a stream is inadequate for a projected rate of use, a dam and reservoir may be constructed to store water for subsequent release to maintain the desired flow. Table 8 shows the frequency with which various amounts of storage are required to maintain selected rates of regulated flow at long-term stream-gaging stations during the reference period. Values of storage required for a recurrence interval of 2 years apply for the condition of median annual streamflow, and values for a recurrence interval of 31 years apply for the condition of lowest annual streamflow. The underlined values in table 8 are greater than the total volume of streamflow in some years and would not be replaced every year. The figures are based on frequency-mass curves, which, in turn, are based on low-flow frequency relationships.

Amounts of storage required to maintain different rates of regulated flow from streams unaffected by regulation are presented in table 9. These data are related to the percentage of the drainage area underlain by stratified drift.

Interpolations between percentages may be made if needed. Storage used to provide regulated flow would be replaced within 1 year, except for the underlined values. Table 9 is based upon an average streamflow of 1.16 (Mgal/d)/mi^2 of drainage area for the reference period, 1930-60. Before the table can be applied to a particular site, the rate of regulated flow and the amount of storage required must be adjusted to the average streamflow at the site by multiplying by an appropriate ratio determined from figure 16.

The required storage shown in tables 8 and 9 are smaller than the true values because they include a bias of about 10 percent, which results from the use of the frequency-mass curves. Moreover, losses due to evaporation and seepage from the reservoir are not included. The amounts shown in the table are sufficiently accurate, however, for reconnaissance planning and for tentative site selection. Furthermore, regulated flow rates assume continuous use and may be increased if use is intermittent.

The example used in the section "Duration of Streamflow" was for a site with a drainage area of 10 mi^2, 20 percent of which is covered by stratified drift, and located where the mean annual streamflow is 0.90 times the statewide average. Suppose it is necessary to determine the amount of storage required to maintain a regulated flow of 5.0 Mgal/d at this site. Adjusting the desired regulated flow for the drainage area at this site results in a unit regulated flow of 0.50 (Mgal/d)/mi^2. The mean annual streamflow at the site is 0.90 times the statewide average of 1.16 (Mgal/d)/mi^2, so the rate of regulated flow and the amount of storage shown in table 9 must be multiplied by 0.90. For a drainage area 20 percent of which is covered by stratified drift, a recurrence interval of 31 years and an adjusted regulated flow of 0.45 (Mgal/d)/mi^2

Table 5.--Lowest daily flows not exceeded during different periods

(Flows are for regulated streams during periods ranging from 7 to 120 consecutive days at long-term stream-gaging stations in the upper Connecticut River basin)

Station no. (pl. A)	Stream and place of measurement	Lowest daily flows (ft^3/s) not exceeded for indicated consecutive days: 7 days	Year	15 days	Year	30 days	Year	60 days	Year	120 days	Year
01184500	Scantic River at Broad Brook	18.1	1957	19.4	1957	19.6	1957	20.4	1957	22.2	1957
01190500	South Branch Park River at Hartford	9.2	1957	9.8	1957	12.8	1957	15.3	1957	18.4	1957
01191000	North Branch Park River at Hartford	.13	1943	.14	1943	.47	1944	.66	1944	1.38	1949
01191500	Park River at Hartford	15.3	1957	15.6	1957	18.3	1941,1943	20.6	1941	27.0	1957
01192500	Hockanum River at East Hartford	12.8	1934	18.0	1930	22.0	1930	25.1	1930	29.5	1930

Table 6.--Lakes, ponds, and reservoirs in the upper Connecticut River basin

(All except Bolton Notch Pond are artifical)

Station no. (pl. A)	Name and location	Drainage area (mi^2)	Surface area (acres)	Surface elevation (ft)	Average depth (ft)	Total storage (Mgal)	Usable storage (Mgal)	Use	Source[1/] of data
01189998	Rainbow Reservoir at Rainbow	582	234.5	98.5	18.6	1825	1731	Power	F.G.
01190097	Batterson Park Pond near Farmington	4.26	162.7	307	14.8	611	611	Recreation	F.G.
01190220	Burnt Hill Reservoir near West Hartford	.38	23.0	264.4	7.4	50.1	50.1	Flood control	S.C.
01190225	Woodridge Pond near West Hartford	1.62	27.9	168	3.3	30.1	30.1	Recreation	F.G.
01190230	Buena Vista Pond near West Hartford	.14	64.1	168	5.5	115	115	Recreation	F.G.
01190245	Hartford Reservoir No. 3 near West Hartford	-	25.6	384	17.4	146	110	Water supply	M.D.C.
01190250	Hartford Reservoir No. 2 near West Hartford	-	44.8	386	19.4	284	213	Water supply	M.D.C.
01190255	Hartford Reservoir No. 5 near West Hartford	-	32.0	320	9.0	94	70.5	Water supply	M.D.C.
01190260	South Reservoir near West Hartford	1.24	55.6	286.7	12.0	218	218	Flood control	S.C.
01190265	Hartford Reservoir No. 1 near West Hartford	-	27	258	5.0	48	48	Power	M.D.C.
01190270	Talcott Reservoir at West Hartford	.69	65.8	450.4	12.5	266	266	Flood control	S.C.
01190280	Bugbee Reservoir near West Hartford	3.31	162	163.6	4.7	248	248	Flood control	S.C.
01190590	Bloomfield Reservoir near Bloomfield	2.88	220	147.5	8.0	567	567	Flood control	S.C.
01190605	Hartford Reservoir No. 6 near West Hartford	1.90	140.8	397	16.6	765	574	Water supply	M.D.C.
01190610	Cold Spring Reservoir near Bloomfield	1.91	128	202.5	9.1	380	380	Flood control	S.C.
01190630	Wintonbury Reservoir at Bloomfield	1.43	150	112.0	5.7	278	278	Flood control	S.C.
01190640	Blue Hills Reservoir near Bloomfield	1.69	226	110.0	3.1	227	227	Flood control	S.C.
01192000	Shenipsit Lake at Rockville	16.4	625	511	26.8	5450	3630	Water supply, industrial	R.W.C.
01192150	Bolton Notch Pond near Bolton	.51	23.9	571	2.1	16.3	16.3	Recreation	F.G.
01192285	Risley Reservoir near Manchester	.82	17	448	11.2	62.5	62.5	Water supply	M.W.C.
01192290	Manchester Reservoir No.2 near Manchester	2.34	2.4	358	19	15	15	Water supply	M.W.C.
01192291	Manchester Reservoir No.1 near Manchester	2.36	1.6	348	19	10	10	Water supply	M.W.C.
01192300	Union Pond near Manchester	53.9	61.3	146	-	-	-	Recreation	Ma.
01192350	Howard Reservoir near Manchester	.85	19.2	489	22	140	117	Water supply	M.W.D.
01192360	Porter Reservoir near Manchester	.60	6.4	418	17	36	27	Water supply	M.W.D.
01192400	Globe Hollow Reservoir near Manchester	2.12	44.8	265	12	170	139	Water supply	M.W.D.
01192630	Buckingham Reservoir near Buckingham	4.56	33.6	453	12	133	124	Water supply	M.W.D.
01192641	Cold Brook Reservoir near East Glastonbury	7.48	10	246	3.1	10	10	Water supply	M.D.C.
01192676	Portland Reservoir near Portland	3.59	42.2	312.6	10.9	150	120	Water supply	P.W.W.
01192679	Nooks Pond at Cromwell	.87	3.4	31	8.3	9.2	9.2	Industrial	C.W.C.

1/ Data chiefly from (F.G.) State Board of Fisheries and Game, (S.C.) Soil Conservation Division, Connecticut Department of Agriculture and Natural Resources, (M.D.C.) Metropolitan District Commission, (R.W.C.) Rockville Water Company, (M.W.C.) Manchester Water Company, (Ma.) Town of Manchester, (M.W.D.) Manchester Water Department, (P.W.W.) Portland Water Works, and (C.W.C.) Cromwell Water Company

Table 7.--Maximum safe draft rates (regulated flows) from selected lakes and reservoirs in the upper Connecticut River basin

(Based on the reference period April 1930 to March 1960. Lakes and reservoirs will refill within a year.)

Station no. (pl. A)	Name and location	Drainage basin	Drainage area (mi^2)	Usable storage (Mgal)	Maximum safe draft rates: Lowest annual flow (ft^3/s)	(Mgal/d)	Median annual flow (ft^3/s)	(Mgal/d)
01190097	Batterson Park Pond near Farmington	Piper Brook	4.26	611	* 2.4	* 1.6	* 6.9	* 4.5
01190605	Hartford Reservoir No. 6 near West Hartford	Tumbledown Brook	1.90	574	* 1.1	* .7	* 2.9	* 1.9
01192000	Shenipsit Lake at Rockville	Hockanum River	16.4	3630	*10	* 6.5	*24	*16
01192400	Globe Hollow Reservoir near Manchester	Hockanum River	2.12	139	* 2.2	* 1.4	3.1	2.0
01192630	Buckingham Reservoir near Buckingham	Roaring Brook	4.56	124	1.3	.85	2.9	1.9
01192641	Cold Brook Reservoir near East Glastonbury	Roaring Brook	7.48	10	1.7	1.1	3.1	2.0
01192676	Portland Reservoir near Portland	Reservoir	3.59	120	1.1	.7	2.8	1.8

* All of the usable storage cannot be used if it is to be completely replenished in one year.

(0.50 x 0.9), the required storage is 46 $Mgal/mi^2$ (51x 0.9), or a total of 460 Mgal for the 10 square mile area (46 x 10). Adjusting for bias, evaporation, and seepage raises this to about 500 Mgal.

FLOODS

Floods have occurred in the upper Connecticut River basin in every month, but in different years. Spring flooding is the most common and usually results from rapid snowmelt and rain. Floods in summer and fall are commonly the result of hurricanes.

Records of flood peak stages on the Connecticut River at Hartford (station No. 01190070) begin in 1639 and are continuous since 1843. Notable flood peak stages, in feet above mean sea level, are:

Date	Stage	Date	Stage
March 20, 1801	27.0	March 21, 1936	37.1
May 1, 1854	29.3	Sept. 23, 1938	34.9
April 21, 1862	28.2	August 10, 1955	30.1
Nov. 6, 1927	28.5	April 7, 1960	27.1

Following the disastrous floods of March 1936 (the highest of record) and September 1938 (the second highest), the top of the dike on the Hartford side of the river was raised to 45 feet above mean sea level, and the top of the dike on the East Hartford side to 40 feet above mean sea level, and several flood-control reservoirs were constructed in the headwaters. At present, about 1,570 square miles of the drainage area of 10,487 square miles upstream from Hartford are controlled by flood detention facilities. These reservoirs would have significantly reduced previous flood peak stages in the above table had they been in existence at the time.

Notable floods have also developed on the tributaries of the Connecticut River in the report area. There were major flood peaks in the Farmington River basin in December 1878, November 1927, March 1936, September 1938, January 1949, and October 1955, but the highest flood peak of record occurred in August 1955. This flood was probably the greatest since 1801 and perhaps since the time of the first settlement at Windsor in 1633. Its peak discharge was more than twice the previous maximum of March 1936 and September 1938. Future floods on the Farmington River, however, will be effectively controlled by Colebrook River Lake and other smaller reservoirs constructed in the basin since 1969. The Scantic River basin underwent severe flooding concurrently and also had its highest flood peak of record in August 1955. The flood had nearly twice the previous maximum discharge of September 1938. In the Park River basin, too, the greatest flood peak of record was that of August 1955, and its peak discharge was more than twice that of October 1955, the second highest known.

Descriptive information on the major floods in New England through 1955 is given by Thomson and others (1964). More detailed records of the major floods of 1936, 1938, and 1955, based primarily on gaging-station records, are contained in Grover (1937), Paulsen and others (1940), U.S. Geological Survey (1947), and Bogart (1960). A partial duration series of all flood peak stages and discharges above a selected base for continuous-record gaging stations within the basin through September 1960 was compiled by Green (1964).

Records of elevation and discharge for flood peaks at long-term stream-gaging stations in the upper Connecticut River basin since November 1927 are are summarized in table 10. Twelve major flood-control reservoirs have been constructed since 1960 by the Corps of Engineers in the Connecticut River basin in Massachusetts and three in the Farmington River basin upstream from Tariffville. Many small flood control reservoirs have also been constructed since 1960 by the Soil Conservation Service. Eight of these are in the Park River basin. These impoundments will significantly reduce future flood peaks. Storage capacities of these reservoirs and others in the upper Connecticut River basin are given in table 6.

MAGNITUDE AND FREQUENCY OF FLOOD PEAKS

Knowledge of the magnitude and frequency of flood peak stages and discharges is essential for land-use planning; design of flood-control structures, highways, and bridges; and for delineation of flood-prone areas. The maximum flood of record and median annual flood at stream-gaging stations in the upper Connecticut River basin are given in table 11. Estimates of the flood flow for any recurrence interval at all the sites listed in table 11 (except the Connecticut River at Thompsonville (station No. 01184000)) and for all ungaged sites within the basin, where the drainage area is 2 mi^2 or more, may be made from figures 19 and 20. For the Connecticut River at Thompsonville, the designated curve on figure 20 should be used with a median annual flood of 95,000 ft^3/s. The median annual flood at a site has a 50-percent chance of occurring in any year and can be found from figure 19 if the drainage area is known. Peak flows for other recurrence intervals up to 100 years (1-percent chance of occurring in any year) are obtainable by multiplying the median annual flood by the appropriate ratio for any selected recurrence interval determined from figure 20. The total area of swamps, ponds, lakes and overflow areas within the basin expressed as percentage of the total drainage area indicates the effect of basin storage on the shape of these curves.

It is emphasized that the upper curves in figures 19 and 20 apply only to unregulated streams draining rural areas; flood peak discharges in urban areas are significantly higher, owing to pavements and storm sewers,

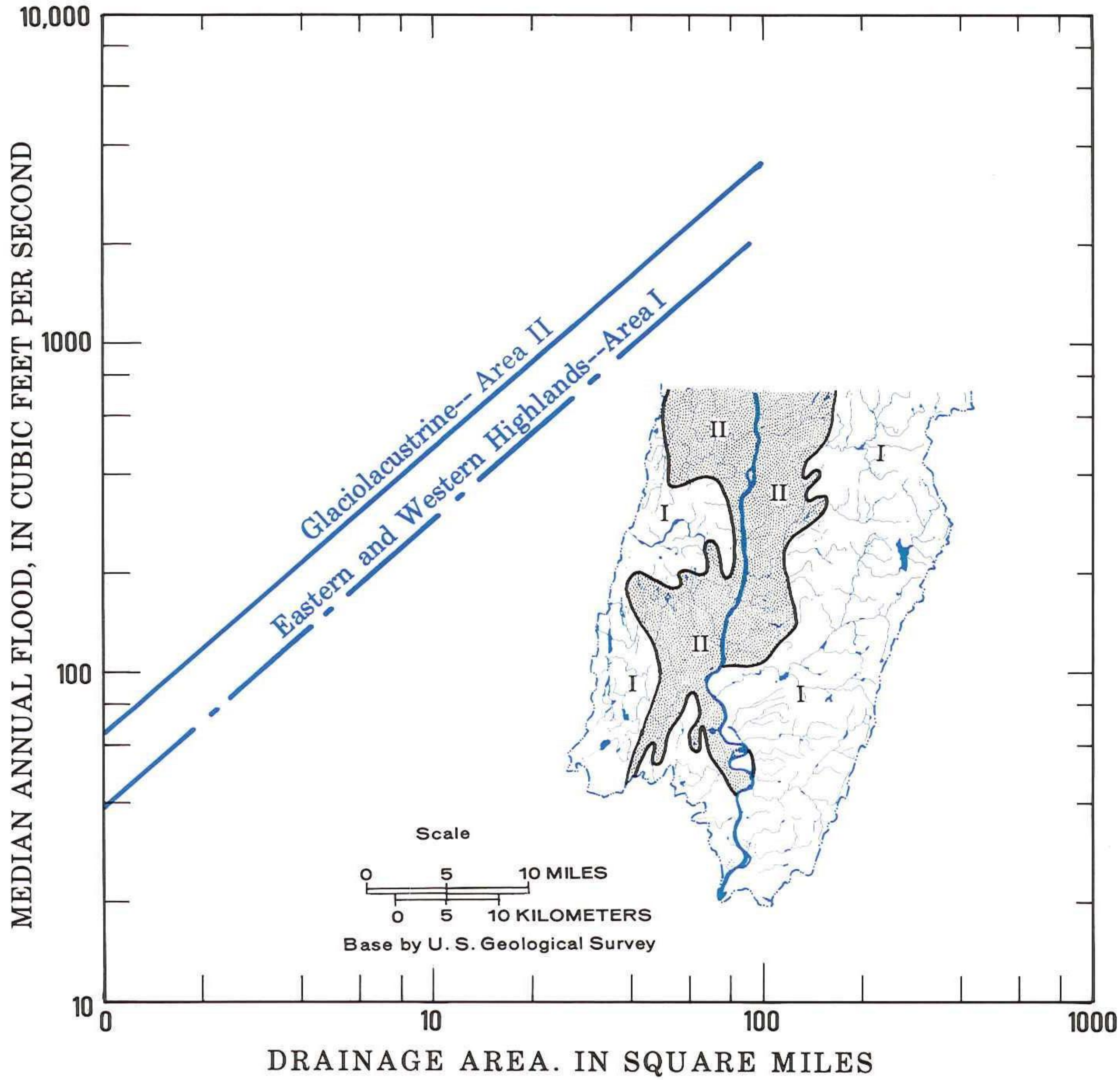


Figure 19.--Graph showing median annual flood in relation to drainage area in the upper Connecticut River basin.

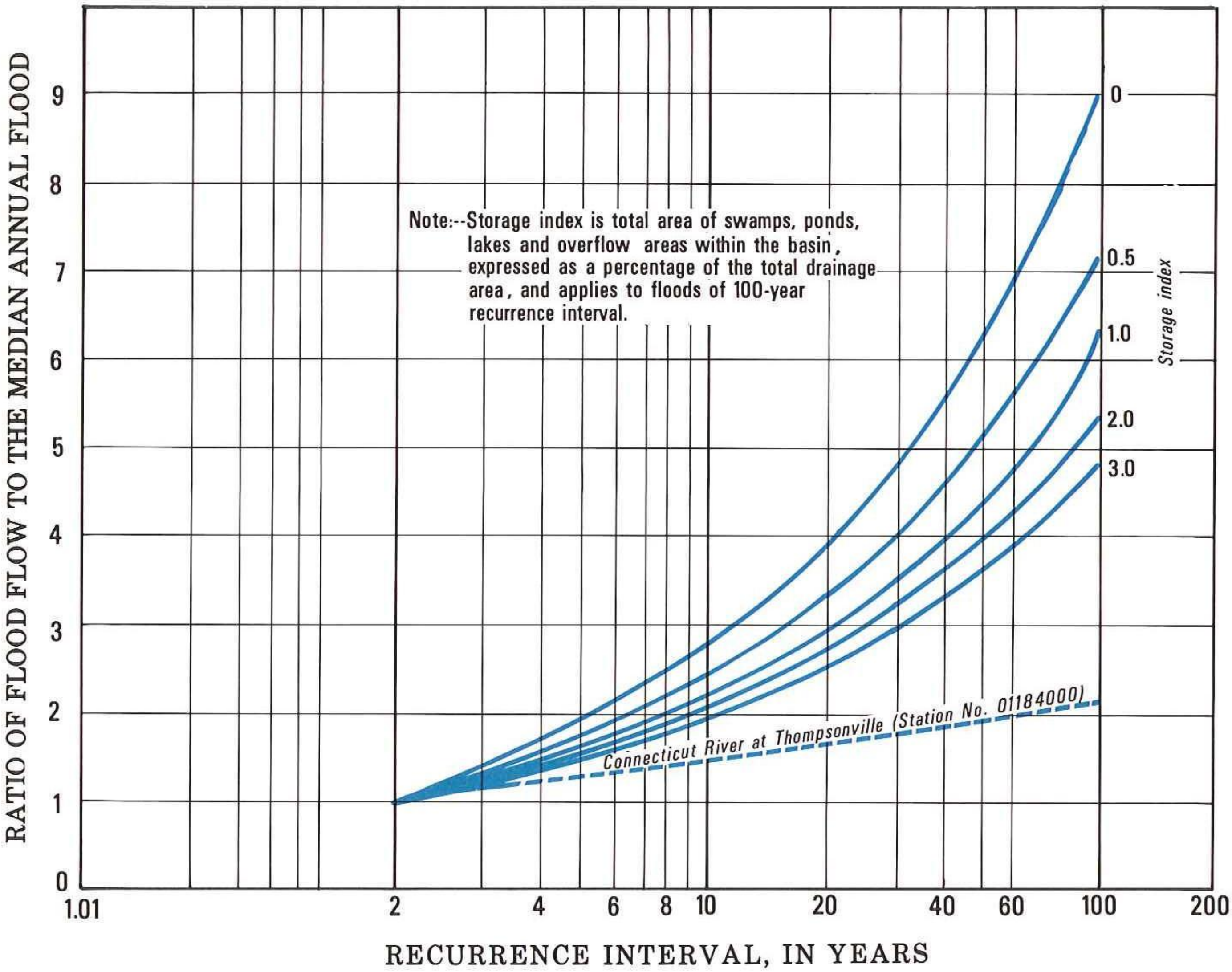


Figure 20.--Graph showing recurrence intervals of peak flows for the upper Connecticut basin.

Upper curves are for unregulated rural drainage basins of less than 100 square miles. Lower curve (dashed), for the Connecticut River at Thompsonville, is flatter because the drainage area is much larger and there is some regulation.

which shorten the concentration time of the runoff.

The terms "recurrence interval" or "return period", as commonly used in comparing the severity of floods, are based upon a continuous series of annual floods. The probability or percent chance of a flood of a given magnitude or greater occurring within any 1 year is the reciprocal of the recurrence interval. In the design of structures, such as bridges or culverts, it is necessary to consider the probability that a peak discharge with a selected annual recurrence interval will be exceeded within the design lifetime of the structure. Table 12 presents this relationship and is based upon the binomial distribution $P = 1 - (1-p)n$, where P is the probability that an annual flood with a selected recurrence interval, or its reciprocal, p, will be equaled or exceeded within n number of years. This relationship has been discussed and elaborated on by Markowitz (1971).

Table 8.--Storage required to maintain regulated flows at long-term stream-gaging stations

(Data are for the upper Connecticut River basin and are adjusted to reference period April 1930 to March 1960. Storage required would refill reservoir within a year except for underlined figures, which would require more time to refill. Storage is uncorrected for reservoir seepage, evaporation, and for bias in computational procedure, all of which increase the amount of storage.)

Station no. (pl. A)	Stream and place of measurement	Drainage area (mi^2)	Recurrence interval of annual lowest mean flow[1] (years)	Maximum amount of storage which would refill during the year of lowest mean flow (Mgal/mi^2)	Storage required to maintain indicated regulated flow [(Mgal/d)/mi^2] 0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.90	1.00
01184500	Scantic River at Broad Brook	98.2	1.2								2	4	6	9	12	16	21	26	33	46	62
			2	57					1	3	5	9	13	18	25	32	39	47	56	77	99
			5	40				1	4	8	15	21	29	37	46	56	68	82	96	126	158
			10	35			1	3	6	13	21	30	40	51	63	75	89	113	119	154	191
			31	30			2	6	13	21	30	40	52	66	81	96	112	128	146	182	218
01190500	South Branch Park River at Hartford	39.9	1.2										2	4	7	10	13	17	21	31	43
			2							2	4	6	9	13	19	26	33	40	49	65	84
			5	70					2	5	9	14	20	26	34	43	53	64	76	98	123
			10	60			1	2	5	8	13	19	26	35	46	56	67	78	90	115	141
			31	52			1	4	8	13	19	28	38	48	59	69	81	93	116	132	161
01191000	North Branch Park River at Hartford	25.1	1.2			1	4	6	8	11	15	19	24	28	34	40	46	53	60	75	90
			2	102	1	4	8	13	18	26	33	41	49	57	67	76	86	96	107	130	155
			5	54	5	11	19	28	38	48	60	72	84	97	111	124	138	152	168	200	232
			10	31	9	17	28	39	52	65	79	93	108	124	142	159	177	196	215	250	287
			31	16	17	30	45	60	76	93	111	128	146	164	183	201	219	238	256	300	329
01191500	Park River at Hartford	72.5	1.2						1	2	3	5	8	11	15	18	23	29	35	47	61
			2						2	5	9	13	18	24	31	37	45	53	62	82	104
			5	51			2	4	7	13	20	27	35	43	52	62	72	84	96	125	156
			10	47			3	7	13	20	27	35	44	54	66	77	91	115	120	151	184
			31	38		3	8	13	21	31	42	53	65	77	91	114	120	135	153	189	226

1/ Values for recurrence intervals of 2 years represent the median year, and those for 31 years, the driest year.

Table 9.--Storage required to maintain regulated flows at sites on unregulated streams

(Data are adjusted to the reference period April 1930 to March 1960 and to an average streamflow of 1.16 Mgal/d/mi^2. Storage required would refill within one year except for figures underlined; these would take longer. Storage is uncorrected for reservoir seepage, evaporation, and for computational bias, all of which increase the amount of storage required.)

Percent of drainage area covered with stratified drift	Recurrence interval of annual lowest mean flow (years)1/	Maximum amount of storage which would refill during the year of annual lowest mean flow (Mgal/mi^2)	Storage (Mgal/mi^2) required to maintain indicated regulated flow [(Mgal/d)/mi^2]																
			0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.90	1.00
0	1.2	--	1	2	3	4	6	9	12	15	18	22	26	30	34	38	43	53	64
	2	--	2	5	8	12	16	21	26	31	37	43	49	56	63	71	79	96	115
	5	108	6	11	17	23	30	37	45	53	62	71	80	90	100	111	122	144	167
	10	97	10	16	23	31	39	48	58	68	79	90	101	113	125	137	149	174	200
	31	69	14	23	32	42	52	63	75	87	99	111	124	137	151	165	179	207	237
10	1.2	--	--	--	--	--	2	4	6	9	12	15	19	23	27	31	36	46	57
	2	--	--	1	3	6	9	13	17	22	27	33	40	47	54	61	68	84	102
	5	97	2	5	9	14	20	26	33	40	48	57	66	75	85	95	105	126	148
	10	90	3	7	13	20	27	35	44	53	63	73	84	95	106	118	130	154	179
	31	67	5	12	20	29	38	47	57	68	80	92	105	118	131	144	158	186	214
20	1.2	--	--	--	--	--	--	1	3	5	8	11	15	19	23	27	31	41	51
	2	--	--	--	--	1	3	6	10	15	20	25	31	37	43	50	58	74	92
	5	90	--	--	3	6	11	16	22	29	36	44	53	62	71	81	91	112	134
	10	83	--	2	6	10	16	23	31	39	48	57	67	77	87	99	111	136	162
	31	60	--	4	9	16	24	33	42	51	61	72	84	96	108	121	135	164	194
30	1.2	--	--	--	--	--	--	--	1	2	4	7	10	13	16	19	23	32	44
	2	--	--	--	--	--	1	3	5	8	12	16	22	28	34	41	48	63	80
	5	83	--	--	--	2	5	9	13	18	24	31	39	47	56	65	75	95	117
	10	77	--	--	1	4	8	14	20	27	34	43	52	62	72	83	94	117	141
	31	61	--	--	3	7	13	20	28	37	47	57	68	79	90	102	115	141	169
40	1.2	--	--	--	--	--	--	--	--	--	1	2	5	8	11	14	18	26	37
	2	--	--	--	--	--	--	--	1	3	6	9	13	18	24	31	38	53	69
	5	76	--	--	--	--	1	3	7	11	16	22	28	35	43	52	61	81	102
	10	72	--	--	--	--	2	6	11	17	24	31	39	48	57	67	78	100	123
	31	59	--	--	--	2	6	12	18	26	34	42	52	62	73	84	96	121	147
50	1.2	--	--	--	--	--	--	--	--	--	--	1	2	4	6	9	12	20	30
	2	--	--	--	--	--	--	--	--	1	3	5	8	12	16	21	27	42	58
	5	68	--	--	--	--	--	1	3	6	10	14	19	25	31	38	46	65	86
	10	65	--	--	--	--	--	2	5	9	15	21	27	34	42	51	61	82	105
	31	56	--	--	--	--	1	4	9	15	22	30	39	48	57	67	78	102	127
60	1.2	--	--	--	--	--	--	--	--	--	--	--	1	2	4	6	9	16	25
	2	--	--	--	--	--	--	--	--	--	--	2	4	7	10	14	19	31	47
	5	61	--	--	--	--	--	--	--	2	5	8	12	17	22	28	35	51	71
	10	59	--	--	--	--	--	--	1	3	7	11	17	23	30	38	47	66	88
	31	52	--	--	--	--	--	1	3	7	13	19	26	34	42	52	62	84	109
80	1.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	2	6	12
	2	--	--	--	--	--	--	--	--	--	--	--	--	1	2	4	6	12	24
	5	--	--	--	--	--	--	--	--	--	--	--	2	4	6	10	14	26	42
	10	50	--	--	--	--	--	--	--	--	--	1	3	6	10	15	21	35	53
	31	47	--	--	--	--	--	--	--	--	1	3	7	12	18	24	31	49	69
100	1.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3
	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	11
	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	3	11	21
	10	--	--	--	--	--	--	--	--	--	--	--	--	--	1	2	6	15	29
	31	--	--	--	--	--	--	--	--	--	--	--	--	1	3	7	12	25	40

1/ Values for recurrence interval of 2 years represent the median year, and for 31 years, the driest year of the reference period.

Table 10.--Flood peaks and corresponding flows for notable floods of record

(Elevation of peaks in feet above mean sea level; flows measured at long-term stream-gaging stations in the upper Connecticut River basin)

Station no. (pl. A)	Stream and place of measurement	Nov. 5, 1927 Elevation (ft)	Nov. 5, 1927 Flow (ft^3/s)	Mar. 12-14, 1936 Elevation (ft)	Mar. 12-14, 1936 Flow (ft^3/s)	Mar. 18-20, 1936 Elevation (ft)	Mar. 18-20, 1936 Flow (ft^3/s)	Sept. 21,22,23, 1938 Elevation (ft)	Sept. 21,22,23, 1938 Flow (ft^3/s)	Aug. 19, 1955 Elevation (ft)	Aug. 19, 1955 Flow (ft^3/s)	Oct. 16, 1955 Elevation (ft)	Oct. 16, 1955 Flow (ft^3/s)
01184000	Connecticut River at Thompsonville 1,2/	-	230,000	47.0	123,000	55.1	282,000	52.9	236,000	49.4	174,000	45.0	92,900
01184500	Scantic River at Broad Brook	-	-	36.4	1,820	3/ 38.5	-	4/ 42.3	7,360	46.1	13,300	33.7	879
01189995	Farmington River at Tariffville 1,2/	-	24,700	141.0	14,900	143.6	26,900	144.2	29,900	-	-	-	-
01190000	Farmington River at Rainbow 1,2,5/	-	-	-	-	-	-	-	-	58.9	69,200	51.7	34,700
01190070	Connecticut River at Hartford 1,2/	28.4	180,000	22.6	130,000	37.0	313,000	34.9	251,000	30.0	210,000	21.9	110,000
01190500	South Branch Park River at Hartford 2/	-	-	43.2	2,500	-	-	44.8	6/ 3,600	50.7	7/ 5,000	46.7	2,800
01191000	North Branch Park River at Hartford 2/	-	-	45.4	2,800	-	-	44.3	2,170	53.0	10,000	46.6	3,680
01191500	Park River at Hartford 2/	-	-	36.1	5,400	-	-	36.1	5,320	43.5	14,000	37.7	6,420
01192500	Hockanum River near East Hartford 1/	-	-	62.6	1,810	60.5	925	68.3	5,160	65.0	2,740	62.5	1,520

1/ Affected by regulation.
2/ Regulation increased since 1960.
3/ Backwater from Connecticut River.
4/ Result of dam failure.
5/ Flood peak for January 1, 1949; elevation 49.2 ft. above msl, 26,500 ft^3/s.
6/ Diversion from basin about 900 ft^3/s not included.
7/ Diversion from basin about 1,500 ft^3/s not included.

Table 11.--Maximum flood of record and median annual flood at stream-gaging stations in the upper Connecticut River basin through 1978

Station no. (pl. A)	Stream and location	Drainage area (mi^2)	Period of continuous record	Maximum flood of record: Date	Maximum flood of record: Elevation (ft above msl)	Maximum flood of record: Flow (ft^3/s)	Maximum flood of record: Flow [$(ft^3/s)/mi^2$]	Maximum flood of record: Ratio to median annual flood	Median annual flood (unregulated): Elevation (ft above msl)	Median annual flood (unregulated): Flow (ft^3/s)	Median annual flood (unregulated): Flow [$(ft^3/s)/mi^2$]
01183990	Jawbuck Brook near Hazardville	2.16	1968-76	Jan. 28, 1976	-	88	40.7	1.76	-	50	23.1
01184000	Connecticut River at Thompsonville	9,661	1929-78	Mar. 20, 1936	55.1	282,000	29.2	2.97	45.3	95,000	9.83
01184100	Stony Brook near West Suffield	10.2	1961-78	Sept. 27, 1975	-	830	81.4	2.86	-	290	28.4
01184260	Namerick Brook near Warehouse Point	2.70	1964-78	Dec. 21, 1973	-	620	230	3.18	-	195	72.2
01184280	Scantic River at North Somers	26.7	1967-69	Mar. 18, 1968	-	1,380	51.7	1.57	-	880	33.0
01184300	Gillett Brook at Somers	3.64	1961-78	Sept. 27, 1975	-	375	103	3.75	-	100	27.5
01184490	Broad Brook at Broad Brook	15.6	1962-76	Sept. 27, 1975	59.8	1,140	73.1	2.59	57.0	440	28.2
01184500	Scantic River at Broad Brook	98.2	1929-78	Aug. 19, 1955	46.1	13,300	135	13.3	34.1	1,000	10.2
01190000	Farmington River at Rainbow	589	1/1913-78	Aug. 19, 1955	58.9	69,200	117	8.65	42.5	8,000	13.6
01190050	Podunk River at Wapping	4.34	1962-76	Mar. 12, 1962	-	320	73.7	2.67	-	120	27.6
01190100	Piper Brook at Newington Junction	14.6	1959-78	Aug. 19, 1955	56.1	2,200	151	3.44	53.3	640	43.8
01190200	Mill Brook at Newington	2.65	1959-78	Sept. 12, 1960	54.3	460	174	2.71	52.1	170	64.2
01190300	Trout Brook at West Hartford	14.6	1959-72	Aug. 19, 1955	90.6	3,300	226	6.00	83.5	2/550	2/37.7
01190500	South Branch Park River at Hartford	39.9	1937-78	Aug. 19, 1955	-	3/6,500	163	4.64	-	2/1,400	2/35.1
01190600	Wash Brook at Bloomfield	5.54	1959-71	Aug. 19, 1955	115.4	3,000	542	11.1	107.8	2/270	2/48.7
01191000	North Branch Park River at Hartford	25.1	1937-78	Aug. 19, 1955	53.0	10,000	398	8.70	41.6	2/1,150	2/45.8
01191500	Park River at Hartford	72.5	1937-62	Aug. 19, 1955	43.5	14,000	193	6.36	33.3	2/2,200	2/30.3
01191900	Charter Brook near Crystal Lake	8.51	1965-78	Dec. 21, 1973	-	1,200	141	7.06	-	170	20.0
01192500	Hockanum River near East Hartford	4/57.0	1920-21, 1929-78	Sept. 21, 1938	68.3	5,160	90.5	5.43	60.2	950	16.7
01192600	South Branch Salmon Brook at Buckingham	.94	1962-76	Sept. 19, 1972	208.4	115	122	4.79	205.7	24	25.5
01192650	Roaring Brook at Hopewell	24.3	1961-76	Apr. 2, 1970	162.8	1,240	51.0	2.70	160.9	460	18.9

1/ Records for 1913-39 at Tariffville, 6 miles upstream.

2/ Does not apply since 1962, owing to construction of flood-control reservoirs and channel improvements.

3/ Includes natural diversion from basin of about 1,500 ft^3/s.

4/ Effective drainage area below Shenipsit Lake at Rockville. Total drainage area 73.4 mi^2.

FREQUENCY AND DURATION OF HIGH FLOWS

The recurrence intervals of instantaneous peak discharges are shown in figure 20. For some purposes, however, it is useful to estimate how long periods of high flow may last and how frequently they may recur. The recurrence intervals of highest mean flows observed for various periods of consecutive days at long-term stream-gaging stations are shown in table 13. Flood flow frequencies for these stations are listed for a period of "0" consecutive days. This table also shows, for example, that for a period of 30 consecutive days, a high mean flow of 77,000 ft^3/s occurred in the Connecticut River at Thompsonville on the average once in 10 years.

Thus, there is a 10-percent chance of a 30-day high mean flow of 77,000 ft^3/s in any 1 year. This flow corresponds to an average stage at the gage of 44.2 feet above mean sea level, as shown in the right side of the table. The instantaneous peak discharge recurring once in 10 years at this site is 175,000 ft^3/s with the corresponding stage of 49.5 feet above mean sea level. This discharge will probably occur in the same 30-day period during which the estimated high mean flow is 77,000 ft^3/s.

Table 13 lists the recurrence intervals of annual highest mean flows for various numbers of consecutive days. The reciprocal of the recurrence interval is the probability of obtaining the mean flow or a greater flow for a specified number of consecutive days within any year. Table 12 can be used to determine the probability that the highest mean flow for a specified number of consecutive days with a selected annual recurrence interval will be exceeded within any design period.

Table 12.--Probability that annual flood discharges will be exceeded in design lifetimes

Recurrence interval of annual flood (years)	Probability - percent chance that annual flood or highest average flow of selected recurrence interval will be equaled or exceeded within indicated design lifetime, in years				
	LIFETIME, IN YEARS				
	1	10	25	50	100
	PERCENT				
10	10	65	93	-	-
20	5	40	72	92	-
50	2	18	40	64	87
100	1	10	22	39	63
200	.5	5	12	22	39
500	.2	2	5	10	18

Table 13.--Annual highest mean flows and corresponding elevations for indicated periods and recurrence intervals

(Shown for long-term gaging stations, based on data for the reference period October 1930 to September 1960)

Station no. (pl. A)	Stream and location	Drainage area (mi^2)	Datum (ft above msl)	Period of consecutive days	Annual highest mean flow (ft^3/s) for indicated recurrence interval (years) 1.05	2	5	10	25	50	100	Annual highest average elevation (ft above msl) for indicated recurrence interval (years) 1.05	2	5	10	25	50	100
01184000	Connecticut	9,661	38.48	0	60,000	105,000	145,000	175,000	215,000	245,000	280,000	43.3	45.7	47.9	49.5	51.6	53.2	55.0
	River at			1	56,000	100,000	139,000	168,000	206,000	235,000	266,000	43.1	45.4	47.6	49.1	51.1	52.7	54.2
	Thompsonville			3	52,000	90,000	126,000	152,000	188,000	217,000	248,000	42.9	44.9	46.8	48.3	50.2	51.7	53.3
				7	45,000	78,000	106,000	125,000	151,000	171,000	191,000	42.5	44.2	45.7	46.8	48.2	49.3	50.4
(Note: Elevations shown				15	38,000	66,000	85,000	97,000	111,000	121,000	131,000	42.1	43.6	44.6	45.2	46.0	46.6	47.1
are for water years through				30	36,000	55,000	69,000	77,000	87,000	93,000	98,000	42.0	43.1	43.8	44.2	44.7	45.0	45.3
1973. Control dam is now				60	25,000	42,000	51,000	56,000	61,000	64,000	67,000	41.3	42.3	42.8	43.1	43.4	43.5	43.7
deteriorating so that				120	20,000	30,000	35,000	38,000	40,000	42,000	43,000	40.9	41.6	41.9	42.1	42.2	42.3	42.4
elevation in April 1979				183	17,000	24,000	28,000	30,000	33,000	34,000	35,000	40.6	41.2	41.5	41.6	41.8	41.8	41.9
are about 1 ft lower				365	12,000	17,000	19,000	21,000	22,000	23,000	24,000	40.2	40.6	40.8	41.0	41.0	41.1	41.2
than those shown.)																		
01184500	Scantic	98.2	26.23	0	520	1,000	1,800	2,800	4,900	7,200	11,000	31.8	34.1	36.2	38.0	40.6	42.6	44.9
	River at			1	490	780	1,400	2,200	3,800	5,800	8,800	31.6	33.2	35.3	37.0	39.3	41.4	43.6
	Broad Brook			3	440	660	1,100	1,600	2,600	3,800	5,600	31.3	32.6	34.5	35.8	37.7	39.3	41.4
				7	320	520	830	1,200	1,700	2,200	2,900	30.1	31.8	33.4	34.8	36.0	37.0	38.1
				15	240	420	620	790	1,100	1,300	1,600	29.4	31.1	32.4	33.3	34.5	35.1	35.8
				30	190	350	490	580	700	800	900	29.0	30.4	31.6	32.2	32.8	33.3	33.7
				60	170	290	380	430	500	550	590	28.8	29.8	30.7	31.2	31.7	32.0	32.2
				120	140	240	300	330	370	400	430	28.5	29.4	29.9	30.2	30.6	30.9	31.2
				183	120	210	260	290	320	340	360	28.3	29.2	29.6	29.8	30.0	30.3	30.5
				365	85	140	180	200	230	240	260	28.0	28.5	28.9	29.1	29.3	29.4	29.6
01190000	Farmington	589	35.36	0	4,400	7,600	14,000	22,000	37,000	55,000	80,000	40.3	42.3	45.1	47.9	52.3	56.3	60.9
	River			1	3,800	7,000	13,000	20,000	33,000	49,000	71,000	39.9	41.9	44.8	47.2	51.3	55.1	59.2
	at Rainbow			3	3,200	5,800	10,000	15,000	25,000	35,000	50,000	39.5	41.3	43.5	45.5	48.9	51.8	55.3
	(Regulated)			7	2,400	4,500	7,400	10,000	15,000	20,000	26,000	38.9	40.4	42.2	43.5	45.5	47.2	49.2
				15	1,800	3,500	5,400	6,900	9,200	11,000	13,000	38.5	39.7	41.0	41.9	43.1	43.9	44.8
				30	1,500	2,800	4,000	4,900	6,300	7,300	8,500	38.3	39.2	40.0	40.7	41.6	42.1	42.8
				60	1,300	2,100	2,900	3,400	4,100	4,700	5,200	38.1	38.7	39.3	39.6	40.1	40.5	40.9
				120	1,000	1,700	2,200	2,500	2,800	3,000	3,200	37.9	38.4	38.8	39.0	39.2	39.3	39.5
				183	900	1,500	1,900	2,100	2,400	2,500	2,700	37.8	38.3	38.5	38.7	38.9	39.0	39.1
				365	610	1,000	1,300	1,500	1,700	1,800	1,900	37.5	37.9	38.1	38.3	38.4	38.5	38.5
01192500	Hockanum	73.4	54.5	0	400	1,000	1,600	2,200	3,400	4,500	6,000	58.5	60.8	62.7	64.2	66.7	68.4	70.6
	River			1	320	610	1,000	1,500	2,200	3,000	4,000	58.1	59.5	60.8	62.5	64.3	66.0	67.7
	near			3	280	450	740	1,000	1,600	2,100	2,800	57.9	58.8	59.9	60.8	62.8	64.0	65.6
	East Hartford			7	210	350	540	710	1,000	1,300	1,600	57.5	58.3	59.2	59.8	60.8	61.9	62.7
				15	160	290	420	520	670	800	940	57.2	58.0	58.6	59.1	59.7	60.1	60.6
				30	130	240	340	400	490	550	620	56.9	57.7	58.2	58.5	59.0	59.3	59.5
				60	120	210	280	320	370	410	450	56.8	57.5	57.9	58.1	58.4	58.5	58.8
				120	100	180	220	250	280	310	330	56.7	57.3	57.6	57.8	57.9	58.1	58.2
				183	93	160	200	220	240	260	270	56.6	57.2	57.5	57.6	57.7	57.8	57.9
				365	72	120	140	160	180	190	200	56.4	56.8	57.0	57.2	57.3	57.4	57.5

Table 14.--Principal water-bearing units in the upper Connecticut River basin

Water-bearing unit	Age	Thickness	General character	Water-yielding properties
Streambed deposits	Holocene	Known to range from less than 1 foot to 34 feet	Complex assemblage of fluvial sediments ranging from clay to boulders. May locally contain significant amounts of organic matter.	Intervening material for ground water moving into streams or for induced recharge of surface water. Hydraulic properties variable.
Stratified drift	Pleistocene	From less than 1 foot to about 300 feet	Interbedded layers of well sorted gravel, sand, silt, and clay. Underlie most major valleys. In some areas, gravel less than 30 feet thick forms a thin cap over underlying fine sand, silt, and clay.	Most important aquifer in the basin where coarse grained, yields of 50 to over 1,500 gal/min can be obtained from properly constructed wells; where fine grained, yields are small.
Till	do	Generally less than 10 feet but ranges from less than 1 foot to about 150 feet	Nonstratified sediment commonly composed of a variety of grain sizes. Discontinuously mantles bedrock and is overlain by stratified drift in valleys.	Generally a poor aquifer because of low hydraulic conductivity and small saturated thickness.
Sedimentary bedrock	Jurassic and Triassic	From less than 1 foot to over 4,000 feet	Consolidated coarse-to-fine-grained bedded rocks of fluvial and lacustrine origin. Individual beds are generally well sorted and partially cemented.	Generally capable of yielding adequate quantities of water for domestic supply and for small commercial, industrial, and public supply. Water occurs in bedding planes, fractures, and intergranular pore spaces.
Igneous bedrock	do	From less than 1 foot to about 800 feet in aggregate thickness	Basaltic lava flows in three units interbedded with sedimentary rocks. Jointing is well defined.	Wells yield quantities generally adequate for domestic supply. Water occurs in joints, fractures, and contact zones.
Crystalline bedrock	Pre-Triassic	Unknown	Metamorphic rocks consisting principally of gneiss and schist. Includes minor amounts of igneous rocks such as granite and pegmatite. Often complexly deformed. Joints and other fractures are most numerous in upper 300 feet.	Wells yield quantities generally adequate for domestic supply. Water occurs in joints and other fractures.

GROUND WATER

Unlike surface water, which occurs in discrete channels at the land surface, ground water occurs everywhere beneath the basin. The water table is essentially the top of the saturated zone below which the earth materials in the basin are filled with water. It is exposed at land surface as springs and swamps and coincides with the water level in most streams, ponds, and lakes. Under nonpumping conditions, the altitude of the water table is highest under hills and lowest at streams. Consequently, ground water moves downward from uplands to adjacent streams, where it discharges and constitutes most of the dry weather flow of streams.

Although ground water seems widespread, its availability varies over the basin and is dependent on several factors. The yield of an individual well, for example, is related to characteristics of the saturated earth materials such as areal extent, hydraulic conductivity, thickness, and storage coefficient as well as to the characteristics of the well such as depth, diameter, and type of finish. The long-term (greater than several months) amount of water that can be pumped by a well or a group of wells is related to all these characteristics as well as to the amount of available recharge.

AQUIFERS

Aquifers are subsurface units composed of earth materials that can yield adequate amounts of water to wells. Two major types of aquifers occur in the basin--those made up of unconsolidated (loose) and more or less easily excavated gravel, sand, silt, and clay and those made up of consolidated (hard) sedimentary, igneous, and metamorphic bedrock. Interbedded sedimentary and igneous bedrock underlies most of the basin, whereas metamorphic and igneous rock, collectively termed crystalline bedrock, underlies the eastern margin. The adequacy of these aquifers to supply water for various uses is summarized in table 14 and briefly discussed in the explanations for plates B and C-2. The areal distribution of the aquifers is shown on plates B and C-1, and a detailed discussion of their water-bearing characteristics and water availability is given in the following sections.

UNCONSOLIDATED AQUIFERS

Unconsolidated deposits form a discontinuous mantle over underlying bedrock and range in thickness from a few inches to at least 250 feet. Two dominant types of unconsolidated deposits, both of glacial origin, occur in the basin: till and stratified drift.

Till (popularly called hardpan), is an unsorted, generally dense mixture of gravel, sand, silt, and clay. Most hilltops and hillsides in the eastern and western parts of the basin and many of the rounded hills in the central part are underlain by till. It directly overlies bedrock at most places and, in turn, is overlain by stratified-drift deposits in valleys in the eastern part and in the broad central valley. Because it has poor water-bearing characteristics, till generally yields only a few gallons per minute to individual wells. Consequently, it is an unreliable source of water even for domestic uses and has largely been abandoned as a source of supply. Till is not considered to be a significant aquifer and is not discussed further in this report.

STRATIFIED DRIFT

Stratified deposits are composed of interbedded layers of generally well-sorted gravel, sand, silt, and clay. These deposits are mostly of glacial origin and are properly called stratified drift. In this report, some younger deposits laid down by post-glacial streams are included with stratified drift, as they are difficult to distinguish separately and have similar water-bearing properties. Stratified drift overlies bedrock or till; it occurs in valley areas in the eastern and western parts of the basin and underlies most of the broad central valley.

Where the stratified drift is well-sorted and coarse-grained, it has excellent water-bearing and water-yielding properties. Saturated stratified drift constitutes some of the major aquifers in the basin, and has the greatest potential for supplying the large quantities of water required for large public-supply and industrial uses. The water-yielding characteristics of stratified-drift aquifers vary, however, depending upon the relative amounts of interbedded fine-grained and coarse-grained materials they contain. Consequently, they are categorized into two major units: coarse grained and fine grained. The distribution of both coarse-grained and fine-grained stratified-drift aquifers is shown on plate B.

The classification of stratified-drift aquifers by grain size is significant for well development. With modern techniques, screened wells can be developed readily in sorted materials coarser than very fine sand but can be developed only with great difficulty in sorted materials of very fine sand, silt, and clay.

Coarse-Grained Stratified-Drift Aquifers

The coarse-grained aquifers are generally made up of layered and sorted materials coarser than very fine sand with incidental layers of very fine sand, silt, and clay. These aquifers are the most productive sources of ground water, particularly where their saturated thickness is greater than 40 feet and they are hydraulically connected to adjacent large streams. The yields of 77 properly developed wells tapping these aquifers range from 40 to 1,300 gal/min, with a median yield of 260 gal/min.

Areas underlain by coarse-grained aquifers are shown on plate B. In these areas, coarse-grained stratified drift either makes up the entire saturated section or is overlain or "buried" by a fine-grained aquifer. Areas where coarse-grained materials are known or inferred to form the entire saturated section of stratified drift are differentiated on plate B from those where they are known or inferred to be overlain by a fine-grained aquifer that is at least 15 feet thick. The extent of some "buried" coarse-grained aquifers that appear to be discontinuous could not be mapped. However, sites where wells or test holes penetrated these unmapped coarse-grained aquifers are indicated on plate B.

"Buried" coarse-grained aquifers can be significant sources of water, especially where they are extensive and thick and are located near large streams. For example, wells EF 82 and 83, which were tested at 350 and 750 gal/min, respectively, each penetrate a coarse-grained aquifer at least 75 feet thick that is overlain by a thick fine-grained aquifer. Few data are available regarding the characteristics of the unmapped "buried" coarse-grained aquifers. Most wells tapping these deposits yield less than 20 gal/min. Well EH 19, however, which is 268 feet deep penetrates 10 feet of coarse-grained material and was tested at 250 gal/min. Test drilling in areas shown on plate B as underlain by "buried" coarse-grained aquifers or near sites where unmapped "buried" aquifers were penetrated should be completed to till or bedrock to adequately determine the thickness and water-bearing characteristics of the "buried" aquifer, if present.

Fine-Grained Stratified-Drift Aquifers

Fine-grained aquifers are more than 200 feet thick in a few places, and primarily consist of layers of very fine sand, silt, and clay. Generally, the upper part of these aquifers is made up of fine to coarse sand and some gravel. This coarser material, which is generally 5 to 20 feet thick and as much as 80 feet thick, may be above the water table at some sites and therefore not saturated.

Fine-grained aquifers, even where thick, can generally supply water to individual wells adequate only for domestic, stock, and limited commercial and institutional uses. The average individual well tapping very fine sand, silt, and clay can be expected to yield 10 gal/min or less. However, wells tapping the uppermost coarse material can be expected to yield more than 400 gal/min in a few favorable locations.

The areal distribution of the fine-grained aquifers is shown on plate B. Areas where fine-grained sediments are known or inferred to comprise the entire saturated section of stratified drift are differentiated from those where upper coarse material is known or inferred to have at least 15 feet of saturated thickness and a potential of yielding at least 400 gal/min to individual wells. The "buried" coarse-grained aquifer unit on plate B defines areas where the fine-grained aquifers overlie the coarse grained. The areal distribution shown on the plate is based on data of differing accuracy, and the overlying coarse material may exceed 15 feet in saturated thickness in additional areas. However, the map is accurate enough for planning and for indicating areas favorable for ground-water exploration.

DEVELOPMENT OF STRATIFIED-DRIFT AQUIFERS BY WELLS

The construction characteristics of a well tapping a stratified-drift aquifer are important determinants of its yield. Well-construction characteristics alone may account for considerably more than half of the drawdown in a pumping well. Consideration of the type of well construction and development best suited for the aquifer at any site is necessary in order to optimize well yield. Several types of well construction are used to develop water from stratified-drift aquifers. All are basically intake structures that allow water to enter the well while preventing the entrance of aquifer materials.

Dug wells, usually lined or cased with concrete or ceramic "culvert" tile or open-jointed fieldstone, as much as several feet in diameter and as deep as a few tens of feet, can be developed in all types of stratified-drift aquifers. However, they are generally the only type of construction that is effective in fine-grained aquifers where the upper coarse material is not saturated. A fine-grained aquifer yields water slowly, but some uses, particularly domestic, are intermittent through a day, and the storage of water in a large diameter dug well can be used to satisfy the intermittent demand. For example, a well 3 feet in diameter dug 10 feet below the water table contains about 530 gallons of water. If the pump intake is set 5 feet above the bottom of the well, about 265 gallons is available for use before pumping. If this amount of water is withdrawn the well would refill to its prepumping level in several hours, at which time another 265 gallons becomes available.

Drilled open-end wells developed in coarse-grained aquifers can supply enough water for most domestic and some commerical uses. This type of construction consists of a blank casing, generally 6 inches in diameter, installed to the bottom of the drilled hole, which commonly ends in sand and gravel or gravel. This construction technique is particularly suitable where a coarse-grained aquifer is overlain by a substantial thickness of a fine-grained aquifer. The yield of open-end wells is generally low because of the large drawdown within the well resulting from the vertical convergence of flow lines in the aquifer toward the bottom of the blank casing during pumping. The yields of 27 open-end wells ranged from 4 to 60 gal/min, and had a median yield of 15 gal/min (Ryder and Weiss, 1971).

Wells of small diameter (generally 4 inches or less) constructed with a blank casing finished at the bottom with a short perforated section (commonly called a well point or sand point) can supply adequate amounts of water for domestic and small-scale commercial, industrial, irrigation, and public water-supply uses. This type of well construction is particularly suitable for developing water from coarse-grained aquifers and from the uppermost saturated coarse material of fine-grained aquifers. However, such wells are generally installed only where the water table is within 20 to 25 feet of land surface because of the common use of suction-type pumps. Greater pumping lifts could be obtained in 2- to 4-inch diameter wells by use of a jet-type pump and in 3- to 4-inch diameter wells by use of a submersible pump. The yields of 42 perforated-casing or screened small-diameter wells ranged from 3 to 100 gal/min and had a median yield of 28 gal/min (Ryder and Weiss, 1971).

Wells greater than 4 inches in diameter finished with a screen and properly developed can yield large supplies of water for industrial, irrigation, and public-supply uses. They are generally constructed with a blank casing finished at the bottom with a continuous-slot or shutter-type well screen of selected length. The size of the open slots or shutters in the screen is commonly based on the grain-size distribution of the adjacent aquifer material. Some well screens may be enclosed within an artificially emplaced envelope of gravel ("gravel-packed"). Large-diameter screened wells are particularly suitable for developing water from coarse-grained aquifers and from the uppermost coarse material of fine-grained aquifers. They are most effective when the screen is set in the deepest part of these water-bearing units as is practicable. The large diameter allows the installation of turbine-type pumps (including submersibles) capable of pumping several hundred or even thousands of gallons per minute. The yields of 77 large-diameter screened wells ranged from 40 to 1,300 gal/min and had a median yield of 262 gal/min (Ryder and Weiss, 1971).

A unique type of large-diameter screened well, termed a "Ranney collector" or "horizontal collector," is occasionally used for developing large supplies of water from coarse-grained aquifers up to 70 feet thick and hydraulically connected to large surface-water bodies. This type of well is exemplified by RH 78 on the west bank of the Connecticut River in the town of Rocky Hill. It consists of a blank reinforced-concrete caisson, 13 feet in diameter, penetrating 63 feet of a coarse-grained aquifer to the underlying bedrock. Two tiers of 13 laterals at depths of 29 and 45 feet extend radially from the caisson outward under the Connecticut River. Each of the 26 horizontal laterals is an 8-inch diameter pipe finished at the end with slots. Pumping from the caisson causes water in the river to move through the streambed into the aquifer and ultimately into the laterals and caisson. The yield of this installation, when completed, was 4,200 gal/min, and in 1958 it pumped as much as 6 Mgal/d on some days.

Effects of Construction Characteristics on the Yield of a Large-Diameter Screened Well

The design of large-diameter screened wells is given careful attention. The relative length of the screened section of a well can have a significant effect on well yield and, more importantly, on specific capacity--the yield, in gallons per minute per foot of drawdown. A typical large diameter well is screened and open to a relatively small fraction of an aquifer--generally the lower part--therefore, the well only partly penetrates the aquifer. The fractional or partial penetration (screen length divided by saturated thickness of the aquifer) of 49 screened wells in the basin ranges from 0.09 to 0.62, with a median of 0.24. Pumping from a partly-penetrating well causes flow lines in an aquifer to converge vertically toward the screen. This results in greater drawdowns in and adjacent to the well than would occur if it penetrated the entire saturated thickness. This additional drawdown can be estimated from data on well diameter, length of pumping period, degree of partial penetration, and the ratio of vertical to horizontal hydraulic conductivity of the aquifer. The estimated additional drawdown can then be subtracted from the total drawdown to determine what the yield and specific capacity would be if the well was fully penetrating. For example, the specific capacity of 53 large-diameter screened wells, calculated from data in the companion hydrologic-data report (Ryder and Weiss, 1971), ranges from 1.3 to 90.1 (gal/min)/ft, and had a median of 16 (gal/min)/ft. The drawdown in 43 of these wells was adjusted for the effects of partial penetration. The resulting adjusted specific-capacity values average three times larger than the unadjusted values. If these 43 wells had been fully penetrating, their yields at the same pumping level would have averaged about three times larger than those reported.

Diameter can also directly affect the yield and specific capacity of a screened well. The combined effects of diameter and partial penetration are illustrated in figure 21. The graphs in this figure suggest that for a screened well to be most efficient, it should have the largest diameter and longest screen possible. However, well-design practice generally limits the expected pumping level in a well to a point at least several feet above

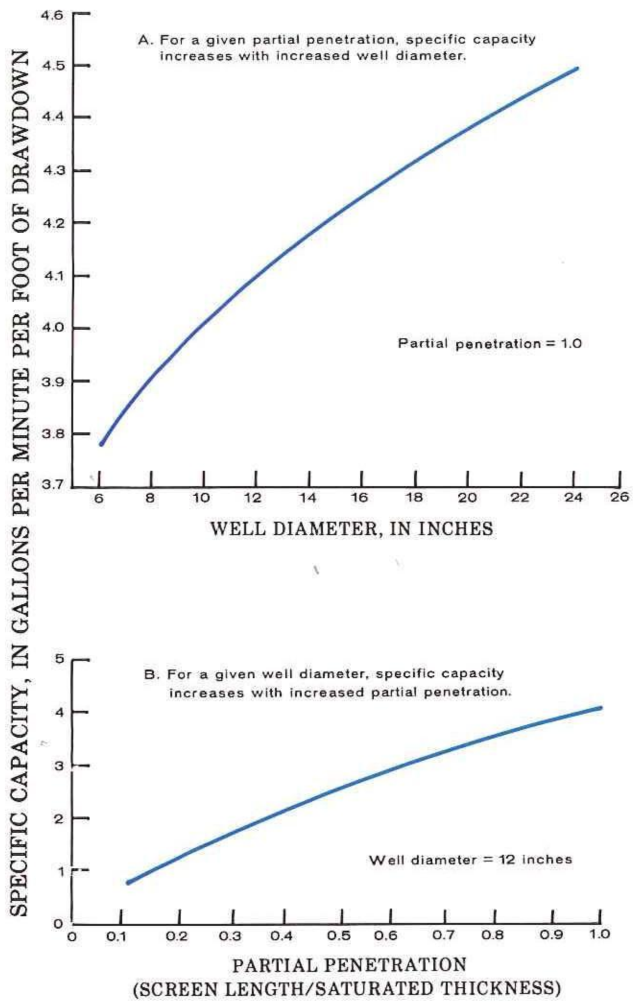


Figure 21.--Graph showing the effects of construction characteristics on the specific capacity of a screened well tapping stratified drift.

Graphs represent conditions for a well tapping a hypothetical aquifer of infinite areal extent where transmissivity = 1,000 ft^2/d, storage coefficient = 0.2, saturated thickness = 80 ft, ratio of vertical to horizontal hydraulic conductivity = 0.1, and duration of constant pumping with no recharge = 180 days.

the top of the screen and, as yield is commonly considered to be directly related to drawdown, a relatively short screen is generally used to increase available drawdown. The net result of this practice, however, is to increase drawdown and decrease yield of the well because of partial penetration effects. A solution to the conflict is to determine the optimum trade

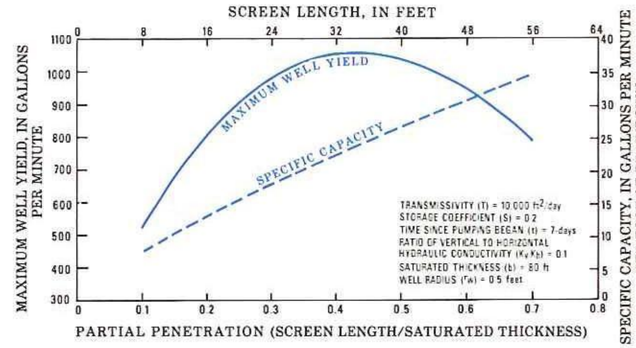


Figure 22.--Graph showing maximum well yields and specific capacity in relation to degree of partial penetration in a screened well tapping stratified drift.

Drawdown 1 ft above top of screen.

off between drawdown and screen length using desired well yield as a guideline. The graph in figure 22 shows the effect that changes in degree of partial penetration have on the yield and specific capacity of a well if the pumping level is kept 1 foot above the screen. Note that specific capacity increases almost linearly with increasing screen length. Yield shows initial increases; reaches a maximum at a partial penetration of about 0.4 and then decreases with increasing screen length. The graph is based on specific aquifer and well characteristics, but the relationships shown apply to all ranges of aquifer characteristics, well diameter, and pumping period. Although a partial penetration of 0.4 seems to be the best trade off based on hydraulic criteria, the cost of the well may also be an important consideration. The cost of a given type of screen is directly related to its length. Note that well yield given in figure 22 increases only 7 percent as partial penetration increases from 0.3 to 0.4, in contrast to a yield increase of 21 percent as partial penetration increases from 0.2 to 0.3. Therefore, a partial penetration of about 0.3 may be economically more favorable than 0.4. The use of this trade-off point results in a shorter and therefore less costly screen while sacrificing only 7 percent loss in well yield.

ESTIMATING THE YIELD OF SCREENED WELLS TAPPING COARSE-GRAINED STRATIFIED-DRIFT AQUIFERS

The yield of a screened well developed in a coarse-grained stratified-drift aquifer is dependent primarily on aquifer characteristics, particularly transmissivity, saturated thickness, and storage coefficient, and on pumping period and well-construction characteristics.

Aquifer Characteristics

Transmissivity.--Transmissivity, expressed as cubic feet of water per day per foot of aquifer width $[(ft^3/d)/ft]$ or, more conveniently, in units of feet squared per day (ft^2/d), is a measure of the water-transmitting capacity of an aquifer. The transmissivity of stratified-drift aquifers, determined at 193 sites, is shown on plate B. These determinations were made primarily for coarse-grained aquifers that make up the entire saturated section and secondarily for the uppermost coarse unit of fine-grained aquifers where it has a saturated thickness greater than 15 feet. A few determinations were made for coarse-grained aquifers overlain by fine-grained aquifers. Transmissivity data for the uppermost coarse unit of fine-grained aquifers apply only to this unit and exclude the underlying fine-grained material. Because these data represent insufficient areal distribution, a transmissivity map could not be constructed. However, transmissivity is presented as site data on plate B to indicate the order of magnitude that might be expected near many sites.

The values of transmissivity were determined through the use of three successively less accurate techniques: (1) analysis of aquifer-test data, (2) analysis of specific-capacity data, and (3) analysis of logs of wells and test holes. The type of analysis used for each site is shown by symbols on plate B.

Aquifer-test data are obtained by pumping a well at a constant rate for a period ranging from several hours to as much as 2 weeks and measuring the rate of water-level decline in observation wells spaced at various distances from the pumping well. The analyses of these data yield the most accurate values of transmissivity. Analytical methods are discussed by Ferris and others (1962), Walton (1962), and Prickett (1965).

Specific-capacity data are obtained by pumping a well at a constant rate for a given period and recording the water level in the well before pumping and again immediately before pumping stops. Specific-capacity data from 43 wells were adjusted for the effects of well radius, partial penetration, and duration of pumping. Transmissivity was then computed from the adjusted specific capacities by modification of an equation by Walton (1962, p. 12).

Transmissivity was estimated for about 100 sites where logs of wells and test holes describe the saturated stratified drift in detail. This method is the least accurate of the three, and some values may be more than 50 percent in error, depending on the detail and reliability of the log. For each site, a value of hydraulic conductivity was assigned to each saturated lithologic unit described in the log by a technique described in Ryder and others (1970), Cervione and others (1972), and Wilson and others (1974). The transmissivity of the entire stratified-drift aquifer was then computed by adding the products of the hydraulic conductivity and saturated thickness of each unit.

Saturated Thickness.--Saturated thickness determines the amount of drawdown available for development and, together with porosity, determines the total amount of water in aquifer storage. The saturated thickness of stratified-drift aquifers is measured vertically from the water table down to the underlying till or bedrock. The saturated thickness of coarse-grained aquifers is shown on plate B for those areas where they make up the entire saturated section of stratified drift. Data are inadequate to define the saturated thickness of "buried" coarse-grained aquifers except in the southernmost part of the basin adjacent to the Connecticut River. The saturated thickness of coarse-grained aquifers ranges from a fraction of a foot near exposures of till and bedrock to at least 160 feet and is 40 to 80 feet in many places.

Storage Coefficient.--The storage coefficient is a measure of the usable amount of water stored in an aquifer. This water is only in temporary storage as it continually moves through the aquifer from areas of recharge to areas of discharge. Aquifer storage changes from day to day, season to season, and year to year in response to changes in rates of recharge and discharge.

A coarse-grained aquifer that makes up the entire saturated section is unconfined; that is, the water table marks the top of the saturated zone, and it is free to fluctuate. The storage coefficient of aquifers under such conditions is essentially equal to the specific yield of the aquifer materials and generally ranges from about 0.05 to 0.30 (Ferris and others, 1962). Storage coefficients calculated from pumping tests of wells EW 90 and M 142, which tap coarse-grained aquifers, are 0.16 and 0.32, respectively. Specific-yield and pumping-test data from similar aquifers in eastern and western Connecticut give average values of storage coefficient ranging from 0.2 to 0.3 (Randall and others, 1966; Thomas and others, 1967; Thomas and others, 1968; Ryder and others, 1970; Cervione and others, 1972). Accordingly, 0.2 was selected as a probably conservative value for coarse-grained unconfined aquifers.

Where a coarse-grained aquifer is overlain by a fine-grained aquifer the hydraulic connection between the two aquifers is poor, and, therefore, the underlying coarse-grained aquifer is generally under artesian conditions. The storage coefficient of artesian aquifers generally ranges from 0.00001 to 0.001 (Ferris and others, 1962). The storage coefficient calculated from a pumping test of well CR 307, which taps a "buried" coarse-grained aquifer, is 0.00035. This value is close to values of 0.0003 and 0.00033 calculated for a similar aquifer in Middletown, Connecticut (Baker, Lang, and Thomas, 1965). These data suggest that the storage coefficient of "buried" coarse-grained aquifers may be approximated by values of 0.0002 to 0.0004.

Pumping Period

When a well is pumped continuously at a constant rate, the critical period is that part of the year during which the aquifer receives little or no natural recharge. If a constant pumping rate can be maintained to the end of this period, it can be continued through the rest of the year when the aquifer receives natural recharge. During this critical period, pumpage is generally obtained from the depletion of aquifer storage unless induced recharge is significant. As a consequence, water levels in the aquifer are lowered in the vicinity of the well, thereby reducing the amount of available drawdown. During the subsequent recharge period, most if not all of the depleted storage is replenished by infiltrating precipitation, thereby raising water levels.

The period of little or no natural recharge in the upper Connecticut River basin generally coincides with the growing season (spring through summer). During this season, most of the infiltrating precipitation is evaporated from the soil or is taken up by plants and then transpired as water vapor to the atmosphere. Therefore, little or no water moves through the unsaturated zone downward to the water table. The average length of the growing season (approximately equal to the frost-free season) ranges from 181 days near the center of the basin, to approximately 165 days at its eastern and western margins (Brumbach, 1965).

Reports in other areas (Randall and others, 1966; Thomas and others, 1967; Ryder and others, 1970; Wilson and others, 1974) indicate that a reasonable estimate of the period of little or no natural recharge over most of Connecticut is approximately 180 days. Likewise, 180 days is considered to be a good estimate of the average length of the period of little or no natural recharge in the upper Connecticut River basin.

Estimating Maximum Well Yield

The maximum yield of a screened well is considered to be that rate that can be sustained through the period of little or no natural recharge and result in a pumping level approximately 1 foot above the top of the screen. The maximum yield of a screened well tapping a coarse-grained aquifer can be estimated by use of the curves in figure 23 that relate yield to saturated thickness for seven values of transmissivity and three values of well radius. These curves apply only for the following conditions: (1) pumping rate is constant through the 180-day period of little or no natural recharge, (2) pumping level at the end of the pumping period is 1 foot above the top of the screen, (3) the screen is set in the lowest third of the aquifer (partial penetration equal to 0.3), (4) the storage coefficient of the aquifer is everywhere approximately equal to 0.2, and (5) the aquifer is more or less uniform and of infinite areal extent for all practical purposes.

The following example illustrates how the curves in figure 23 and the data on plate B can be used to estimate maximum well yield. At a hypothetical site, plate B indicates that the saturated thickness of a coarse-grained aquifer that makes up the entire saturated section of stratified drift is approximately 70 feet, and the transmissivity at a nearby site is 5,000 ft^2/d. The curves in figure 23 indicate that a properly developed well at this site having a diameter of 8 inches (radius of 0.333 feet) and 21 feet of screen set at the bottom of the aquifer (partial penetration equal to 0.3) can be expected to have a maximum yield of approximately 300 gal/min through the period of little or no natural recharge (180 days).

AREAS FAVORABLE FOR LARGE-SCALE DEVELOPMENT OF GROUND WATER

Eighteen areas probably most favorable for the large-scale development of ground water for industrial, commercial, irrigation, and public-supply uses are shown on plate C-1. These areas were selected because of the following favorable geohydrologic conditions: (1) they are underlain by a coarse-grained aquifer that in most places makes up the entire saturated section of stratified drift, (2) the saturated thickness of the aquifer is at least 40 feet, and (3) they are traversed by a stream or streams that have an individual or aggregate 30-day, 2-year mean low streamflow equivalent to at least 1 Mgal/d. These conditions are considered to be significant criteria because the amount of water that can be pumped from an area depends partly on aquifer characteristics, especially transmissivity and saturated thickness, and partly on the long-term "dependable" streamflow that can be induced to infiltrate into underlying and adjacent aquifers by pumping wells.

Under conditions of ground-water development, the natural hydraulic gradient in an aquifer, which is toward the stream or streams traversing the favorable area, will be locally reversed, and part or all the water in the stream may be induced to flow into the aquifer toward the pumping well(s). Such "induced recharge" supplements the water available from aquifer storage and decreases the amount of drawdown required to produce a given amount of water per unit of time. The amount of induced recharge available depends on several hydraulic characteristics and chiefly upon the long-term quantity of stream water available. Several low streamflow statistics can be calculated as indices of available streamflow. However, the one that seems to have the most significance is the 30-day, 2-year mean low streamflow, which is shown on plate C-1 for many streams. This is simply the mean of the flows that would occur during the 30-consecutive days

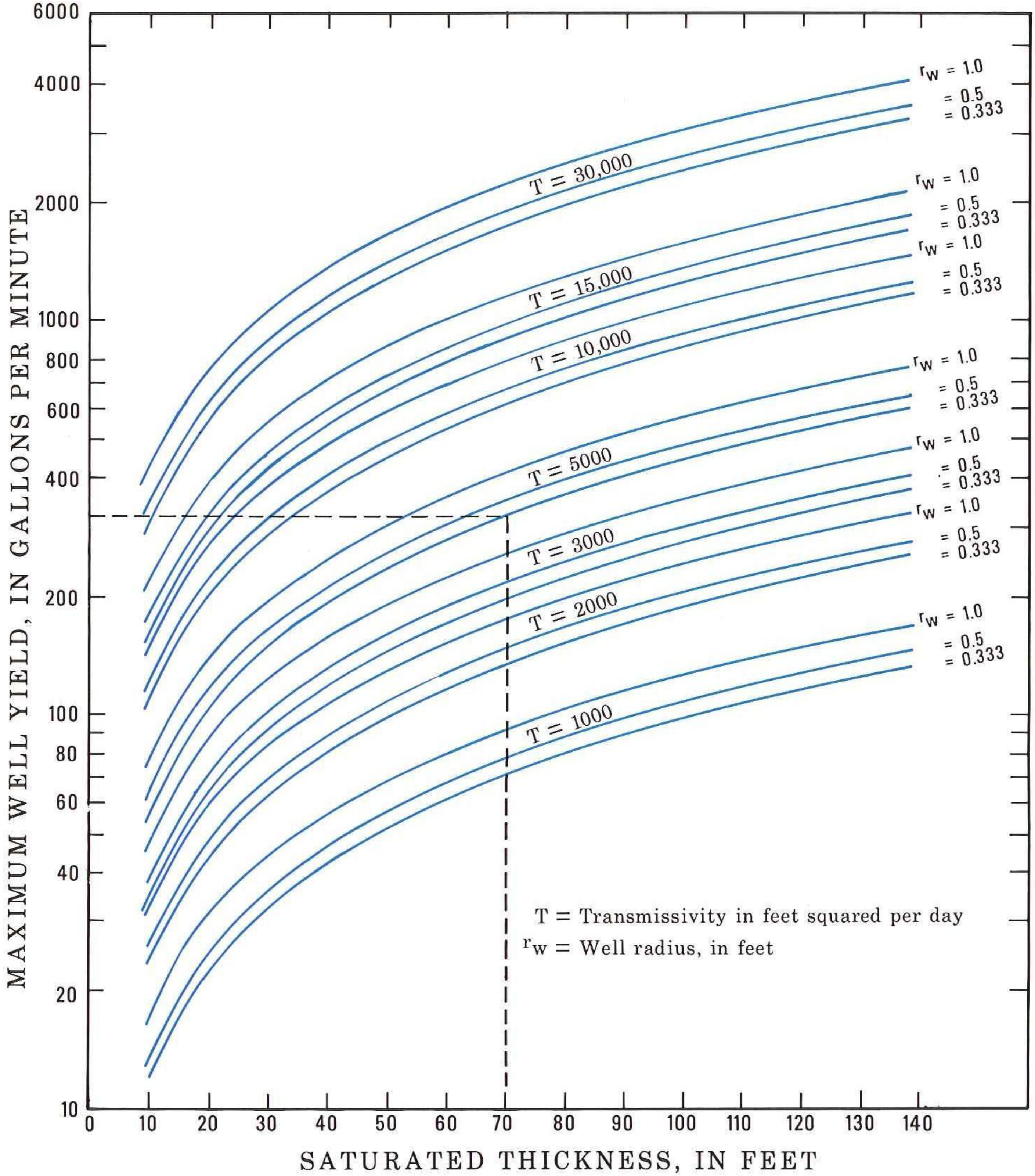


Figure 23.--Graph showing maximum well yield in relation to aquifer characteristics and well radius of a screened well tapping stratified drift.

Maximum well yield (yield with drawdown 1 ft above top of screen) is directly related to saturated thickness and transmissivity of a stratified-drift aquifer and to radius of the well. Curves shown apply to an aquifer of infinite areal extent pumped at a constant rate for a 180-day period of no recharge. Partial penetration = 0.3; storage coefficient = 0.2.

EXAMPLE

THE VERTICAL DEPTH, IN FEET, FROM THE LAND SURFACE TO THE TOP OF THE UNDERLYING BASALT (V) AT WELL SITE "C" CAN BE ESTIMATED AS FOLLOWS.

$$V = (H)\ (\tan\alpha) - E$$

$$V = (600\ \text{ft})\ (0.27) - 50\ \text{ft} = 110\ \text{ft}$$

where: H = 600 feet, The shortest horizontal distance between well site "C" and the upper contact of basalt

$\tan\alpha$ = 0.27, The tangent of the dip (angle at which the basalt stratum is inclined from the horizontal).

E = 50 feet. The altitude at the upper contact of the basalt (800 feet) minus the altitude at well site "C" (750 feet).

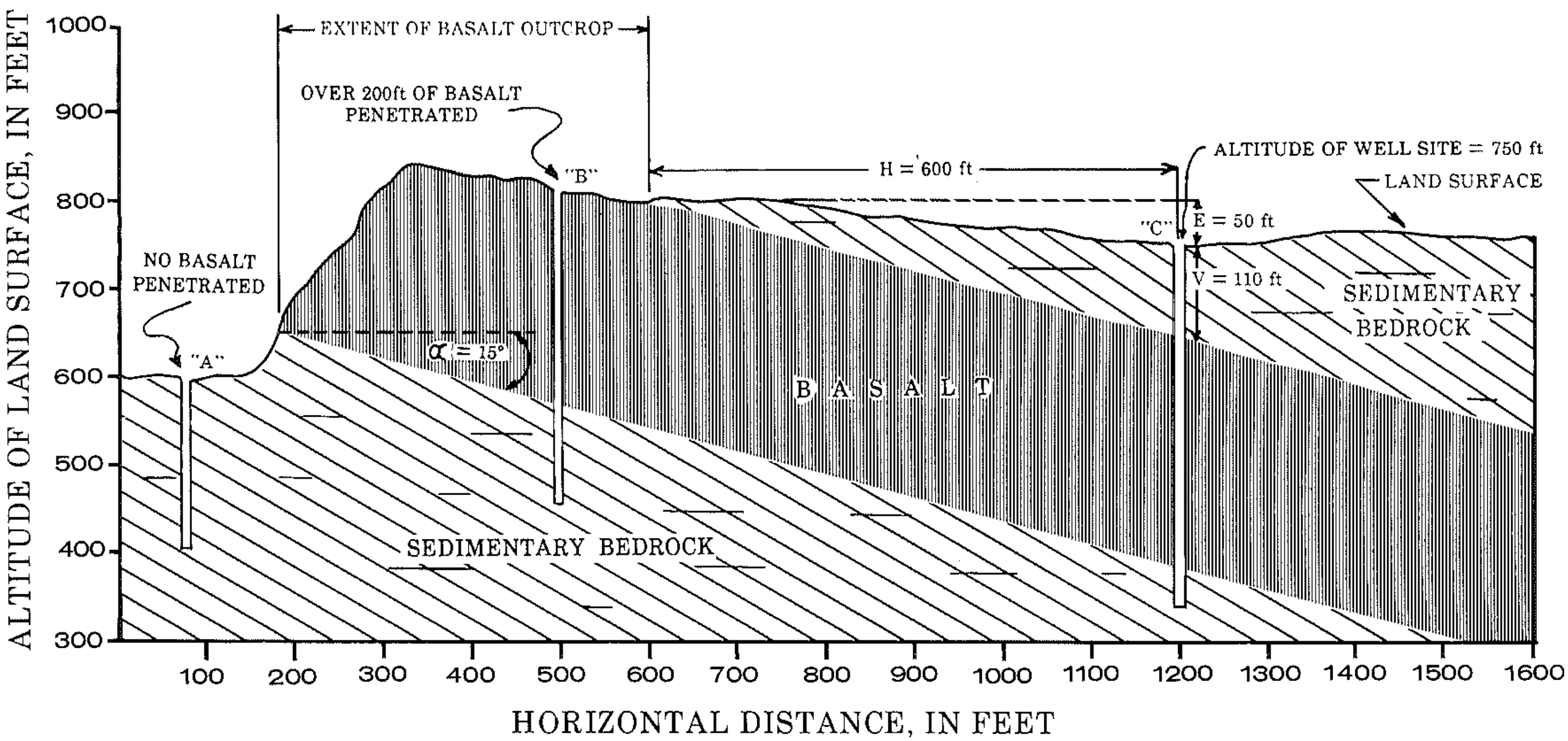


Figure 24.--Cross section showing geometric relationship between sedimentary and igneous (basalt) rocks.

A well drilled into sedimentary rock in the basin may penetrate basalt at depth (See pl. C) or, as shown at site "B", a well drilled into basalt may penetrate sedimentary rock at depth.

that had the lowest daily flows in any year and that has a 50 percent chance of occurring in any year on a long term basis. In the upper Connecticut River basin, this is approximately equivalent to the long-term 90-percent flow duration.

No accurate estimate of the quantity of ground water available for development from the 18 favorable areas could be made, as the data regarding transmissivity and boundary conditions of the aquifers are insufficient to permit the use of analytical techniques or mathematical models. However, the 30-day, 2-year low flow of streams entering the favorable areas does provide a rough index of the dependable amount of water available. Such data for large streams should, however, be used with caution, particularly if the 30-day, 2-year value is 10 Mgal/d or greater. The quantity of ground water available in areas traversed by such streams can be significantly smaller than the streamflow shown on plate C-1, as the hydraulic characteristics and boundary conditions may not allow such a large quantity of water to infiltrate the aquifer or to be pumped from wells.

Areas other than those shown on plate C-1 may also be favorable for large-scale development if they are: (1) underlain entirely by a coarse-grained aquifer with less than 40 feet of saturated thickness, or (2) underlain by a fine-grained aquifer that has a relatively thick saturated upper coarse-grained unit, as in the vicinity of the town of Windsor Locks, or (3) underlain by a relatively thick "buried" coarse-grained aquifer. However, in general, the potential of these areas will be smaller than that of the 18 selected.

BEDROCK AQUIFERS

Bedrock, commonly called "ledge", underlies the entire basin, and, except for localized exposures, is overlain by variable thicknesses of unconsolidated deposits. Bedrock is saturated with water at some depth everywhere in the basin, and forms significant aquifers. For example, 90 percent of the 426 domestic wells listed in table 1 of the companion hydrologic-data report (Ryder and Weiss, 1971) tap bedrock.

The major bedrock units are: (1) interbedded sedimentary and igneous and (2) crystalline. The areal distribution of these units is shown on plate C-2. The sedimentary rocks can supply water to individual wells in quantities adequate for most domestic and commercial uses and many industrial, irrigation, and public-supply uses. In contrast, the crystalline rocks can supply water to individual wells in quantities adequate only for domestic and small-scale commercial uses.

WELL CONSTRUCTION

Wells tapping bedrock aquifers have essentially the same type of construction regardless of bedrock type or intended use. In general, a hole 6 to 12 inches in diameter is drilled through any unconsolidated material present and into underlying bedrock either by the compressed-air down-hole hammer or cable-tool method. In both methods, the unconsolidated material is kept out of the hole by setting blank casing into the underlying hard rock. After the casing is set, drilling in rock is generally continued until an adequate yield is obtained. The finished well consists of the blank casing extending through the unconsolidated materials and into underlying bedrock, and the open hole extends downward into the bedrock. The open hole permits water in the rock fractures to flow into the well bore.

SEDIMENTARY AND IGNEOUS ROCKS

This bedrock unit which is made up or red, brown, and grey sedimentary rocks, as much as 16,000 feet thick (Krynine, 1950), and three layers of igneous rocks, as much as 800 feet in aggregate thickness (Lehmann, 1959) underlies the western two-thirds of the basin. The igneous rocks, predominantly basalt (commonly called "traprock") directly underlie the western and southern parts (see plate C-2), where they form prominent ridges, such as Talcott Mountain. These rocks have been tilted about 15^{o} from the horizontal and, consequently, dip to the east almost everywhere in the basin, particularly in the southwestern part, which was subjected to faulting. The direction of tilt or dip is indicated by symbols on plate C-2. The three tilted layers of basalt extend from their mapped outcrop on plate C-2 eastward under progressively greater thicknesses of sedimentary bedrock. In addition, the rocks are overlain by as much as 250 feet of unconsolidated material. (See plate C-2.)

Basalt

Basalt is a dark greenish-grey rock made up of a dense interlocking network of minerals. In fresh outcrops it is characteristically broken by both horizontal and more closely spaced vertical fractures. Because of the density of this rock, almost all the ground water occurs in these fractures. Therefore, the yield of a well drilled into basalt is dependent primarily upon the number, width, and degree of interconnection of the water-bearing fractures penetrated during drilling - characteristics that cannot be reliably predicted. The yield of a well tapping basalt, consequently, cannot be estimated before drilling by methods such as those described for stratified-drift aquifers. Generally, basalt yields enough water to individual wells for domestic and light commercial and irrigation uses. The yield of 21 wells tapping basalt ranges from 3 to 125 gal/min and averages 19 gal/min (Ryder and Weiss, 1971). At some places, however, wells have been drilled entirely through basalt and into underlying sedimentary bedrock in order to obtain adequate yield.

Because of the geometric relationships between the basalt and sedimentary rocks, wells drilled into sedimentary bedrock may penetrate basalt at depth. This is particularly true in areas that are within 1,500 feet in the dip direction (generally to the east) of the nearest surface contact between basalt and sedimentary bedrock. The depth below land surface at which basalt may be penetrated can be estimated. It is approximately equivalent to the shortest horizontal distance, in an up-dip direction, between the well and the nearest basalt contact multiplied by 0.27 (the tangent of 15^{o}) plus or minus the difference in altitude between the land surface at the well and that at the contact. An example of this depth estimation is shown in figure 24, with examples of rock units to be expected at depth at different locations.

Sedimentary Rocks

Sedimentary rocks are characteristically red to reddish brown and are made up of beds of shale, mudstone, sandstone, arkose, and some limestone. These beds range in thickness from a few inches to several feet (Krynine, 1950; Lehmann, 1959; and Schnabel, 1960) and generally dip 10 to 15^{o} to the east.

The water-bearing characteristics of these rocks are inadequately defined. Most ground water probably occurs in fractures, as in basalt, and in openings along the planes that separate the individual beds. Some water however, may occur in intergranular openings, as it does in unconsolidated aquifers.

Data from pumping tests of two wells tapping sedimentary rocks in the town of Cromwell, just outside the basin (Bingham, Paine, and Weiss, 1975, table 7), indicate that these rocks are hydraulically homogeneous in the vertical direction but have horizontal directional differences in their water-transmission properties. Directional differences have also been observed in similar rocks in New Jersey (Vecchioli, 1967; Vecchioli and others, 1969).

Sedimentary rocks, unlike basalt, can supply water to individual wells in quantities adequate for most large-scale uses. The yield of 580 wells tapping sedimentary rocks ranges from less than 1 gal/min to 586 gal/min, with a mean of about 50 gal/min. Of these wells, 75 percent were drilled for domestic use, which generally requires 10 gal/min or less. Their yields therefore, are not a proper index of the potential of the aquifer for other larger uses. In contrast, of the the other 25 percent drilled for higher-demand uses, 30 percent have a yield of at least 150 gal/min, and 10 percent have a yield of at least 376 gal/min.

Well yields without additional information do not adequately indicate the productivity of the sedimentary rocks. Analysis of data from 401 wells tapping only sedimentary rocks shows that, in general, yield is directly related to drawdown. Specific capacity is, therefore, a more useful measure of water-yielding potential than yield data alone. The information shown

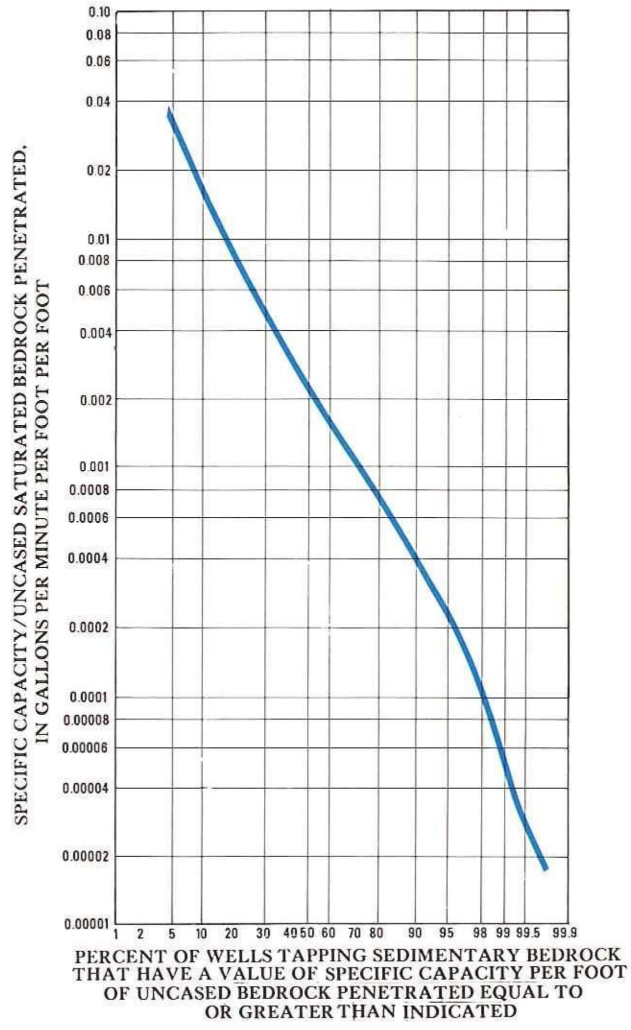


Figure 25.--Graph showing cumulative-frequency distribution of specific capacity divided by length of uncased saturated bedrock for 401 wells tapping sedimentary bedrock.

in the following table indicates that specific capacities of the 401 wells are a function of the amount of uncased saturated bedrock penetrated (amount of uncased saturated bedrock is equal to the depth of the well minus the depth to the static water level or bottom of the casing, whichever is greater).

Thickness of uncased saturated bedrock penetrated (ft)	Median specific capacity [(gal/min)/ft]
1 to 200	0.17
201 to 300	.31
301 to 500	.85
greater than 500	1.3

These data indicate that a well open to a greater thickness of uncased saturated bedrock will generally yield more at a given drawdown than a well open to a lesser thickness. The reason for this may, in part, be that the hydraulic conductivity of component beds of the sedimentary rocks is generally uniform and does not decrease with depth, at least for thicknesses of saturated bedrock up to about 650 feet. Therefore, wells open to lesser thicknesses of uncased saturated bedrock have greater drawdowns for a given yield. They only partly penetrate the aquifer, which results in additional drawdown.

To depict the relationship of yield to drawdown and thickness of uncased saturated bedrock, the specific capacity of each of the 401 wells was divided by the length of uncased saturated bedrock it penetrated. The cumulative frequency distribution of the resulting values is shown in figure 25. This curve indicates, for example, that 50 percent of the 401 wells have a specific capacity equal to or greater than 0.0021 gal/min per foot of drawdown per foot of uncased saturated bedrock penetrated.

The total depth of a well finished in sedimentary rocks is equivalent to the thickness of the overlying unconsolidated deposits plus the thickness of unsaturated bedrock, if any, plus the thickness of saturated bedrock required to give the desired yield. The thickness of unconsolidated deposits overlying sedimentary rocks and basalt can be estimated by the thickness units shown on plate C-2.

Crystalline bedrock

Crystalline rocks that underlie the eastern margin of the basin are light-grey to greenish-black metamorphic and igneous rocks that include gneiss, schist, gabbro, and pegmatite (Collins, 1954; Aitken, 1955; Herz, 1955). These rocks are similar to basalt in that they are made up of a dense interlocking network of minerals. In this dense network, there is little or no space between the mineral grains; therefore, the water occurs principally in fractures. The yield of a well in crystalline rock is dependent on the number, width, and degree of interconnection of the water-bearing fractures intersected by the open well bore. As these fractures are generally small and widely separated, crystalline rocks can supply quantities of water adequate only for domestic and small-scale commercial and public-supply uses. The yield of 28 wells tapping crystalline rocks ranges from 0.7 to 25 gal/min, with a median yield of 9 gal/min (Ryder and Weiss, 1971).

The areal and vertical distribution of the water-bearing fractures is largely unknown; therefore, the yield of a well tapping crystalline rocks cannot be estimated with any certainty before drilling. However, the vertical distribution of fractures, and, thus, well yield, can be described as a chance phenomenon. Accordingly, data from 21 wells were analyzed statistically. The resulting relation between yield increase and thickness of saturated bedrock that wells were drilled into or through is shown in figure 26. Assuming that the data shown in the figure are representative of all of the crystalline rocks in the basin, they can be used to approximate the chances of obtaining a desired yield by drilling deeper. For example: a well penetrating 50 feet of saturated bedrock yields 4 gal/min; figure 26 indicates that drilling into an additional 50 feet of rock provides a 75 percent chance that the yield will not increase, a 50 percent chance that it will be at least 5.25 gal/min (1.25 gal/min increase), and a 10 percent chance that it will be at least 8 gal/min (4 gal/min increase).

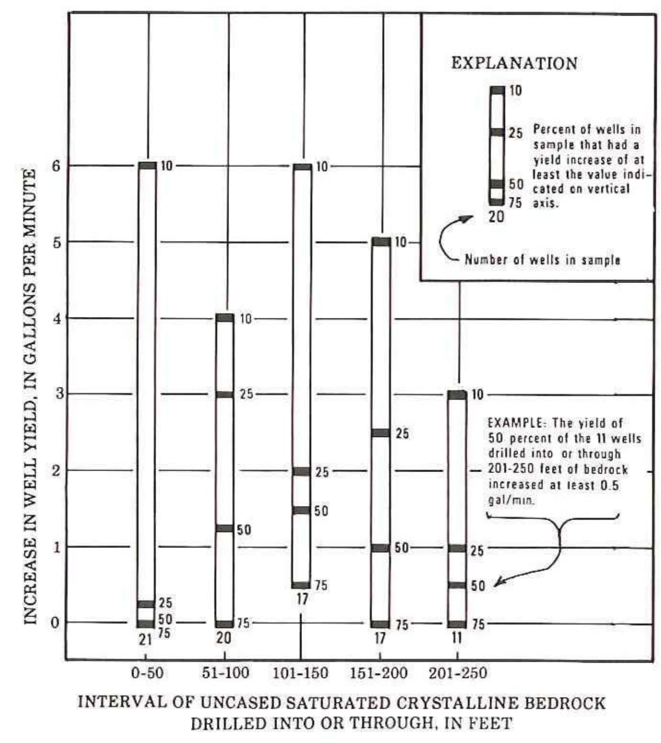


Figure 26.--Graph showing estimated change in yield of a well tapping crystalline bedrock as a result of increasing the depth.

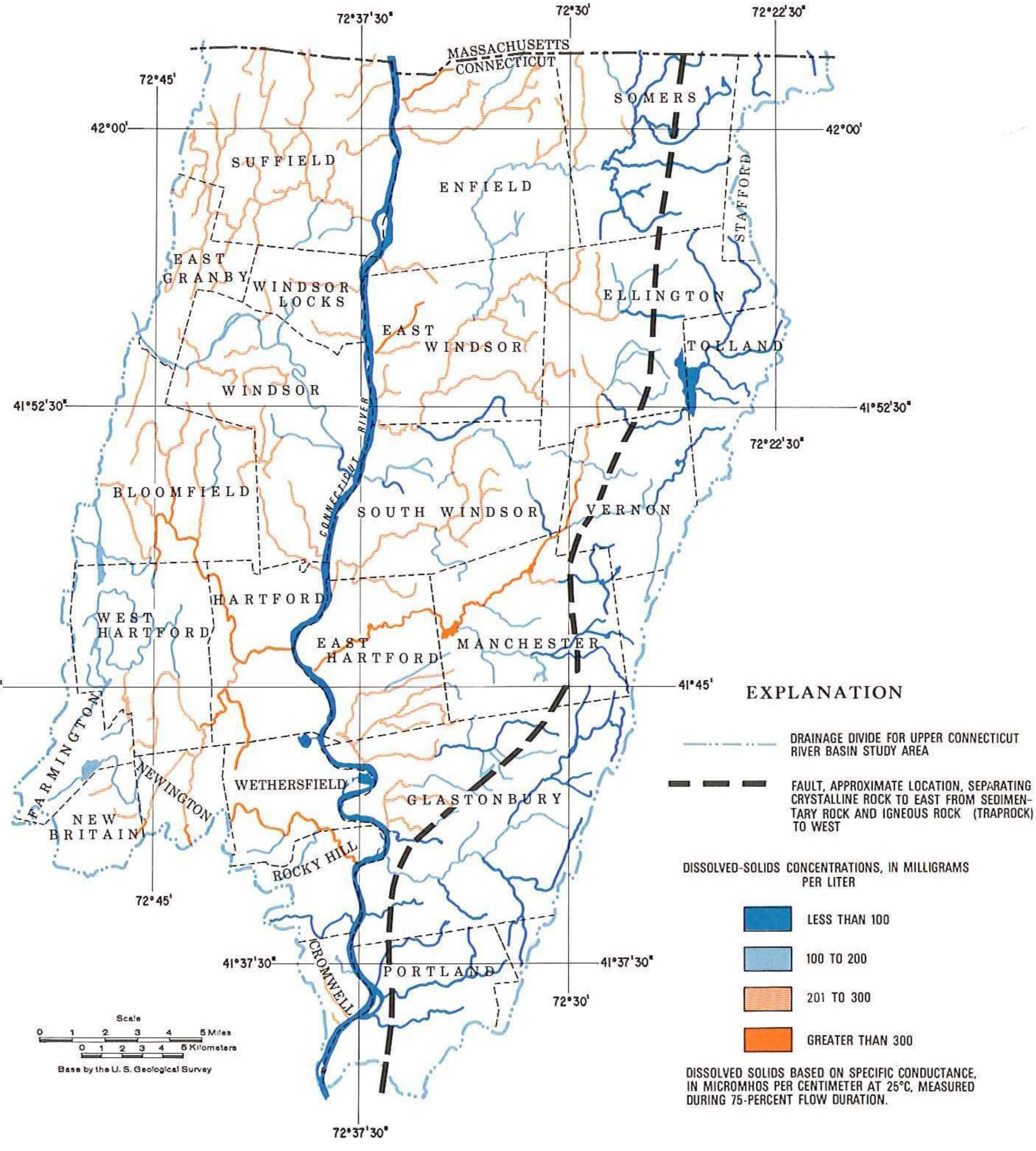


Figure 27.--Map showing maximum concentration of dissolved solids in surface water in the basin at low-flow conditions.

QUALITY OF WATER

The water in streams is derived from ground-water and surface-water runoff, and its quality largely depends on the quality and proportions of these two sources. When streamflow is low, practically all the flow is ground-water runoff, and its composition is similar to that of ground water. The chemical quality of ground water in areas unaffected by man depends on the minerals in the earth materials and their solubility in ground water.

Therefore, the areal distribution of dissolved-solids concentration of surface water during low streamflow can provide an indication of the natural chemical quality of ground water and its relation to the geology. Water in streams at high flow is a mixture of ground-water runoff and surface-water runoff, and its chemical quality is intermediate. The physical quality of water during high flow is affected by suspended sediments and is related to the erodibility and type of earth material being eroded.

Man's activities alter the chemical and physical quality of surface water. Sediment loads, for example, may be augmented by earth materials disturbed by construction or by farming. Chemical quality can be altered by crop fertilization, road salting, sewage disposal, and refuse disposal near streams.

The quality of ground water may also be affected by fertilizers, road salts, septic-tank leaching fields, leachates from solid-waste disposal, infiltration from streams carrying waste, water-softening effluents, and by leachates from industrial-waste lagoons.

STREAM QUALITY

CHEMICAL QUALITY

Dissolved solids

The areal distribution of dissolved solids in streams during periods of low flow (flow duration approximately equal to 75 percent) is shown in figure 27. During low flow, dissolved-solids concentration is related to the bedrock geology. The bedrock units west of the Eastern Border Fault (see figure 27) are sedimentary and igneous (traprock); those east of the fault are crystalline (metamorphic and igneous). The cementing agents and vein fillings in the sedimentary and igneous rock include calcium carbonate and other soluble secondary minerals, such as sodium and calcium sulfate. These compounds are readily dissolved in ground water. The minerals in the crystalline rocks, however, are not as easily dissolved. Streams draining areas underlain by crystalline rocks had dissolved-solids concentrations less than 200 mg/L along their entire lengths. Streams draining areas underlain by sedimentary and igneous rock generally had dissolved-solids concentrations greater than 200 mg/L.

Water samples from streams such as Namerick and Goff Brooks (stations 01184260 and 01192670, plate A) show the natural high dissolved-solids content of the water discharged from the sedimentary bedrock and traprock at low flow. The concentrations exceed 300 mg/L. However, the dissolved-solids concentrations in water from the Hockanum and Park Rivers (stations 01192500 and 01191500, plate A), are affected by waste-water discharges along the urbanized parts of their courses.

A summary of the chemical and physical quality of water for 25 stream sites during high flow (approximately equal to 5 percent flow duration) and low flow (approximately equal to 80 percent flow duration) is shown in table 15. These sites were selected because their water quality is probably affected least by man. The dissolved-solids concentrations during high flow ranged from 38 to 203 mg/L, with a median of 113 mg/L. The dissolved-solids concentrations during low flow ranged from 54 to 400 mg/L, with a median of 148 mg/L. The median concentration during low flow for nine sites on streams draining areas underlain by metamorphic rock was 74 mg/L, and that for 16 streams draining sedimentary and igneous rock was 164 mg/L. The major ions consist primarily of calcium, magnesium, bicarbonate, sulfate, sodium, and chloride. Figure 28 shows the relation between runoff and specific conductance, a measure of dissolved-solids concentration, for four streams from

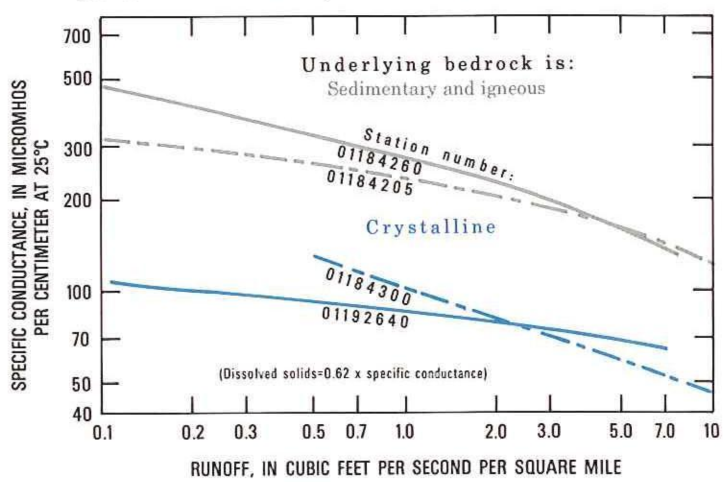


Figure 28.--Graph showing specific conductance of water in relation to magnitude of streamflow and type of underlying bedrock.

which data were collected weekly. The ratio of dissolved solids (residue on evaporation at 180°C) to specific conductance was 0.62 for streams in the basin. The water in Namerick and Muddy Brooks (stations 01184260 and 01184205, plate A) has a higher dissolved-solids concentration for a given runoff than Gillette and Cold Brooks (stations 01184300 and 01192640). The drainage areas of Namerick and Muddy Brooks are underlain by sedimentary and igneous rock, which contain soluble cementing agents, whereas the drainage areas of Gillette and Cold Brooks are underlain by less soluble crystalline rock.

Iron and manganese

Iron and manganese in surface waters are derived primarily from minerals and from decaying vegetation (Hem, 1970, p. 116, 126). During low flow, their concentrations in stream water are a result of ground-water inflow, which may include swamp drainage (Randall and others, 1966, p. 38). During high streamflow, their concentrations are the result of ground water mixed with surface-water runoff. Figure 29 shows the areal distribution of the concentrations of both of these constituents for periods of high and low flow at 25 sites. The maximum concentrations of iron and manganese recommended by the U.S. Environmental Protection Agency (1976) for domestic water supply, 0.3 mg/L and 0.05 mg/L, respectively, are used in this inventory as the limits for high concentrations for these two constituents. Concentrations greater than recommended may cause discoloration of porcelain fixtures and laundry.

Table 15 shows iron and manganese concentrations in streams at high flow (5 percent flow duration) and low flow (80 percent flow duration). Values for 25 streams at high and low flow and the bedrock type underlying the drainage area are given in the table. Sixteen of the 17 high-flow samples from areas underlain by sedimentary and igneous rock had iron concentrations greater than 0.3 mg/L. Only two of the 25 low-flow samples exceeded 0.3 mg/L of iron. Manganese concentrations exceeding 0.05 mg/L were found in 24 of the high-flow samples and 18 of the low-flow samples. Most of the high-flow samples containing high concentrations of iron and manganese were from streams draining areas underlain by glacial lake deposits.

Analysis of water samples from 107 wells tapping sedimentary and igneous rock indicated that 30 samples had iron and manganese concentrations in excess of 0.3 and 0.05 mg/L, respectively. Most of the ground-water samples exceeding the above limits were collected west of the Connecticut River.

Nitrate and phosphate

Nitrate and phosphate do not occur naturally in large concentration in earth materials in the basin (McKee and Wolf, 1963). Their greatest sources in streams are fertilizers, vegetal decay, and sewage. Nitrate concentrations at 25 stations ranged from 0.1 to 31 mg/L, with a median of 3.2 mg/L at a low flow equal to a flow duration of 80 percent. The phosphate concentrations in water for eight stations ranged from 0.04 to 1.7 mg/L, with a median of 0.24 mg/L at the same low flow. The nitrate concentrations for the 25 stations at a high flow, equal to a flow duration of 5 percent, ranged from 0.2 to 8.9 mg/L, with a median of 3.5 mg/L. The phosphate concentrations for the same high flow, for nine stations, including the eight sampled during low flow, ranged from 0.17 to 0.67 mg/L, with a median of 0.45 mg/L.

The loads in pounds per day per square mile of drainage area [$(lb/d)/mi^2$] for both of these constituents sampled during the 1968 water year at stations on 12 streams (table 16) are grouped by the predominant land-use patterns (Connecticut Development Commission, 1962). In general, streams in basins having larger proportional areas of urban or agricultural land have higher nitrate loads.

PHYSICAL QUALITY

Suspended sediment and turbidity

The concentration of suspended sediment carried by streams varies with the flow, the velocity, the water density, the size of the sediment particles, and the availability of erodible material.

Fine-grained surficial deposits are more erodible than coarse-grained deposits and yield more suspended sediment to streams. Turbidity is one measure of suspended sediment and is reported here as silica (mg/L). Water from 12 sites on streams draining areas underlain by extensive glacial lake (fine-grained) deposits (see plate B) had a median turbidity of 40 mg/L as silica at a streamflow equal to 5 percent flow duration. In contrast, turbidity in water from 13 sites on streams draining areas without extensive glacial lake deposits was 4 mg/L as silica at the same flow duration.

Figure 30 shows the relations between turbidity and streamflow, land use, and presence of glacial lake deposits for four selected streams based on one high flow and one low flow sample. Charter Brook (station 01191900) is in the headwaters of the Hockanum River basin and drains a rural area that has no extensive glacial lake deposits. In contrast, a tributary of the Scantic River basin (station

Table 15.--Quality of water in streams at high flow and at low flow
(Chemical and physical quality of selected streams mostly unaffected by man in the upper Connecticut River basin. Nitrate and phosphate values affected by fertilizing practices and chloride affected by road salt.)

Concentration in milligrams per liter (mg/L) except as noted 1/

Constituent or property	At high flow 2/			At low flow 3/			At low flow 3/				
							In 17 drainage basins underlain by sedimentary and igneous rocks		In 8 drainage basins underlain by crystalline rocks		Recommended upper limit in drinking water 4/
	Median	Min	Max	Median	Min	Max	Minimum	Maximum	Minimum	Maximum	
Silica (SiO_2)	6.7	4.2	10	8.9	4.4	13	4.4	13	5.6	13	--
Iron (Fe)	.49	.10	3.4	.04	.00	.44	.00	.30	.00	.44	--
Manganese (Mn)	.16	.04	.45	.08	.01	.29	.01	.17	.02	.29	--
Calcium (Ca)	13	3.6	29	22	4.2	86	13	86	4.2	15	--
Magnesium (Mg)	3.2	.9	9.0	5.2	.0	16	1.2	16	.0	2.6	--
Sodium + Potassium (Na+K)	7.8	3.7	33	9.0	5.5	18	5.5	18	5.8	14	5/ 20
Bicarbonate (HCO_3)	22	4	78	43	12	127	21	127	12	34	--
Sulfate (SO_4)	27	9.4	41	25	5.9	162	22	162	5.9	15	--
Chloride (Cl)	10	3.9	41	15	4.9	31	7.4	31	4.9	25	250
Nitrate (NO_3)	3.5	.2	8.9	3.2	.1	31	.6	31	.1	2.4	6/ 10
Phosphate (PO_4)	7/ .45	7/ .17	7/ .67	8/ .24	8/ .04	8/ 1.7	-	-	-	-	--
Dissolved solids (residue at 180°C)	113	38	203	148	54	400	99	400	54	101	--
Hardness as $CaCO_3$	50	12	107	77	10	281	48	281	10	46	--
Noncarbonate hardness as $CaCO_3$	26	9	68	30	0	177	23	177	0	22	--
Specific conductance (micromhos at 25°C)	127	51	288	197	52	611	150	611	52	156	--
pH (units)	6.5	5.8	7.1	7.2	6.6	7.7	6.7	7.7	6.6	7.4	--
Color (platinum-cobalt units)	25	8	100	6	2	50	2	32	2	50	9/ 20 - 250
Turbidity (mg/L as SiO_2)	20	2	150	2	.8	20	.8	20	.8	25	--

1/ Statistics based on one sample from each of 25 streams except as indicated.
2/ Flow equaled or exceeded less than 5 percent of the time, based on records for base period 1931-60.
3/ Flow equaled or exceeded more than 80 percent of the time, based on records for base period 1931-60.
4/ Upper limit recommended by Connecticut Department of Health [Connecticut General Assembly, (1975)].
5/ Finished water.
6/ Nitrite + nitrate as N.
7/ Based on one sample from each of 9 streams.
8/ Based on one sample from each of 8 streams.
9/ Depending on type of treatment.

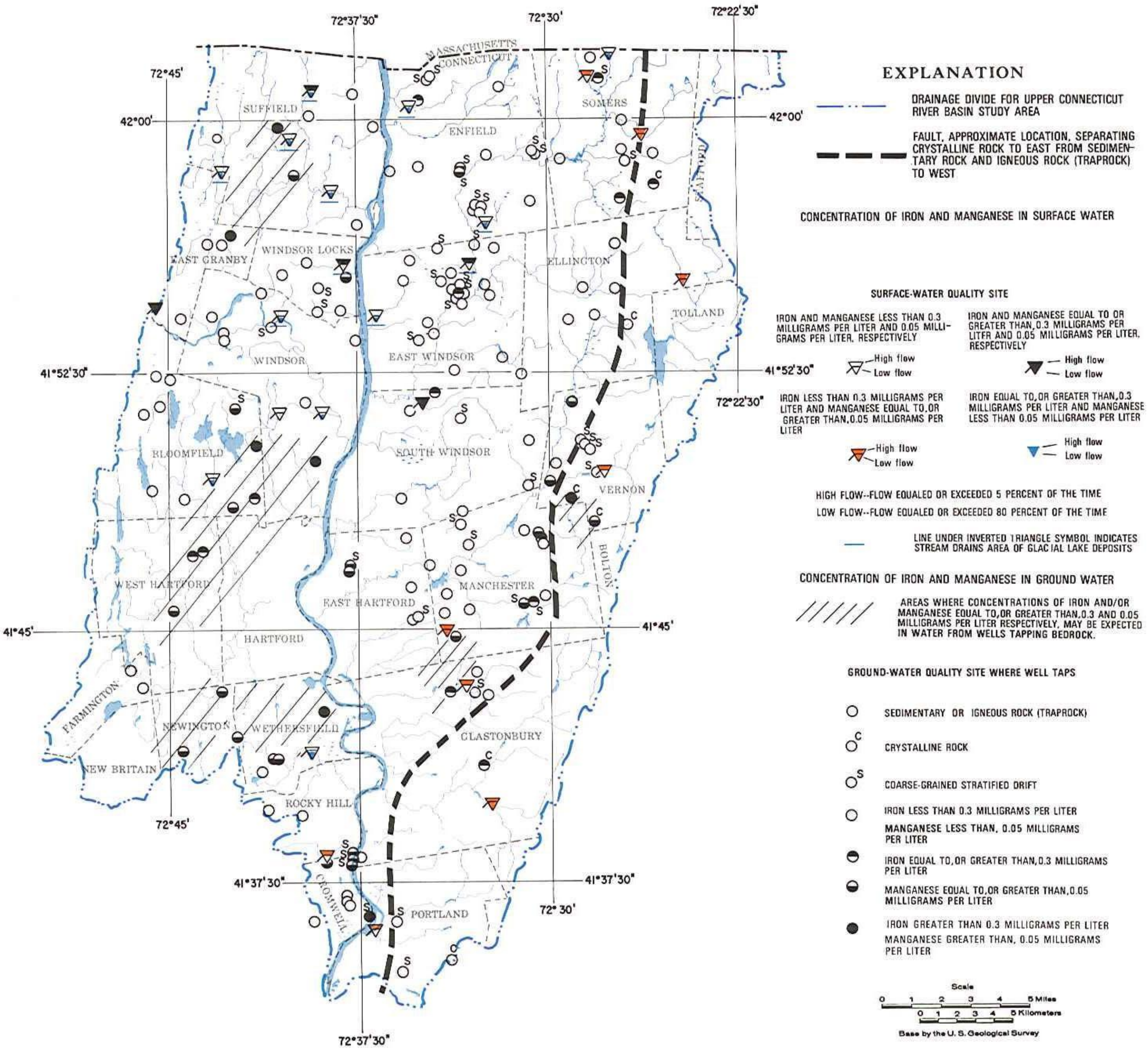


Figure 29.--Map showing areal distribution of iron and manganese in surface water and ground water.

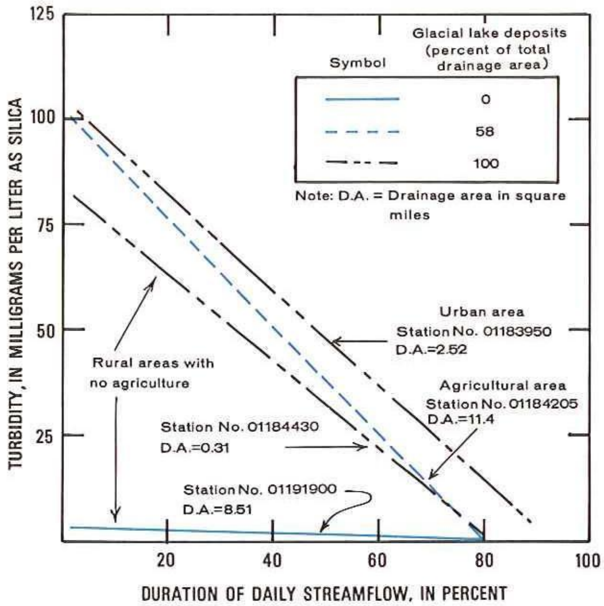


Figure 30.--Graph showing turbidity of streams in relation to duration of flow, glacial lake deposits, and land use.

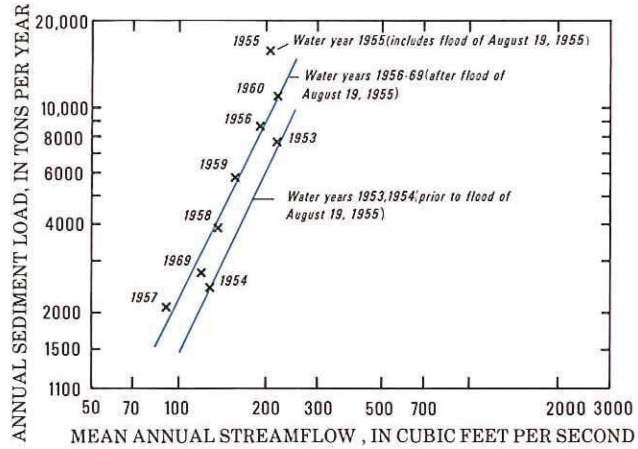


Figure 31.--Graph showing variation in annual sediment load of the Scantic River.

01184430) drains a similar rural area that is completely underlain by glacial lake deposits.

Muddy River (station 01184250) is in the headwaters of the Stony Brook basin, drains a rural area 58 percent of which is underlain by glacial lake deposits. Unlike the basin upstream of station 01184430, the land is farmed. Grape Brook (station 01183950) drains an urban area 100 percent underlain by glacial lake deposits. Both Muddy River and Grape Brook had higher turbidities than the rural nonagricultural areas (stations 01191900 and 01184430).

Scantic River.--Suspended-sediment concentrations in the Scantic River were measured during the 1969 water year at stations 01184280 and 01184500. The drainage areas upstream from both sites are essentially rural. The drainage area above station 01184280 is 30.8 square miles, 25 percent of which is underlain by coarse-grained stratified drift and 75 percent by till. The drainage area upstream from station 01184500 is 98.4 square miles, 11 percent of which is underlain by lake deposits, 34 percent by coarse-grained deposits, and 55 percent by till. The mean suspended-sediment load at station 01184280 for the 1969 water year was 0.43 ton per day, or 0.01 ton per day per square mile. The mean value at station 01184500 for the same period was 7.6 tons per day, or 0.08 ton per day per square mile. The load at station 01184280 during a storm on March 26, 1969, was 2.3 tons per square mile, and at station 01184500, during the same storm, it was 37 tons per square mile. Streamflow at both sites was 7.1 $(ft^3/s)/mi^2$. Although land use and streamflow were similar, the suspended-sediment load per square mile of drainage area at station 01184500 was almost 20 times that at station 01184280. The glacial lake deposits upstream from station 01184500 probably contributed greater concentrations and, therefore, greater loads.

Suspended-sediment concentrations and streamflow were also measured at station 01184500 during water years 1953-60. Figure 31 shows annual loads versus mean annual flow for each water year. The 1955 water year shows a large increase in the suspended-sediment load over the 1953 water year, for the same streamflow. This is attributed to the hurricane of August 19, 1955, which resulted in large quantities of surface runoff and erosion of the land surface and stream banks. After the 1955 water year, the relationship between annual sediment load and mean annual streamflow appears to have changed slightly as compared to 1953-54.

Temperature

Temperature affects the chemical, physical, and biological properties of surface water. Stream temperature depends on solar radiation, temperature of ground-water runoff, stream depth and flow rate, and man's discharge of effluents. The daily durations for sites on six streams are shown in figure 32. These

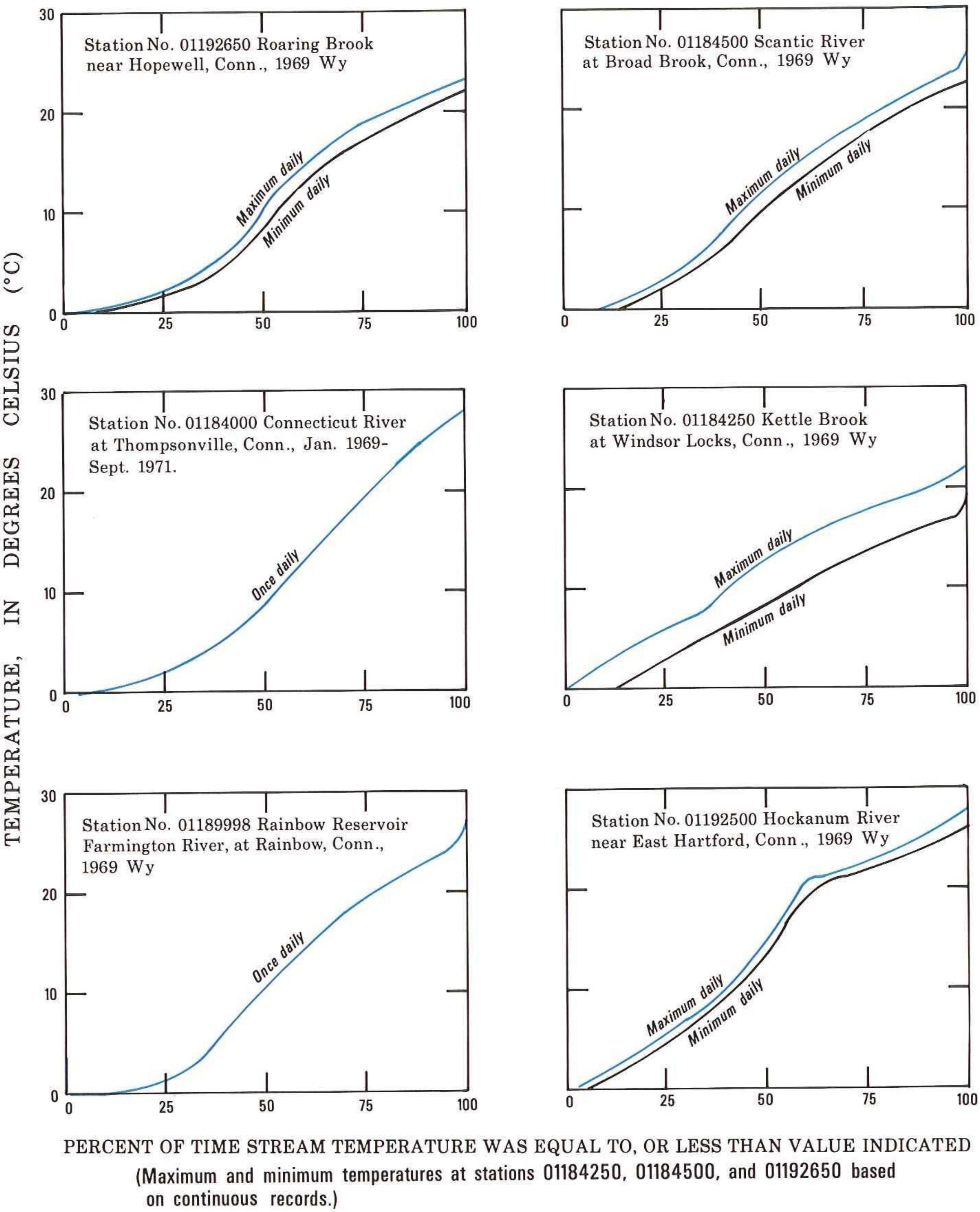


Figure 32.--Graph showing daily duration of temperature in six streams in the upper Connecticut River basin.

Maximum and minimum temperatures at stations 01184250, 01184500, and 01192650 based on continuous records.

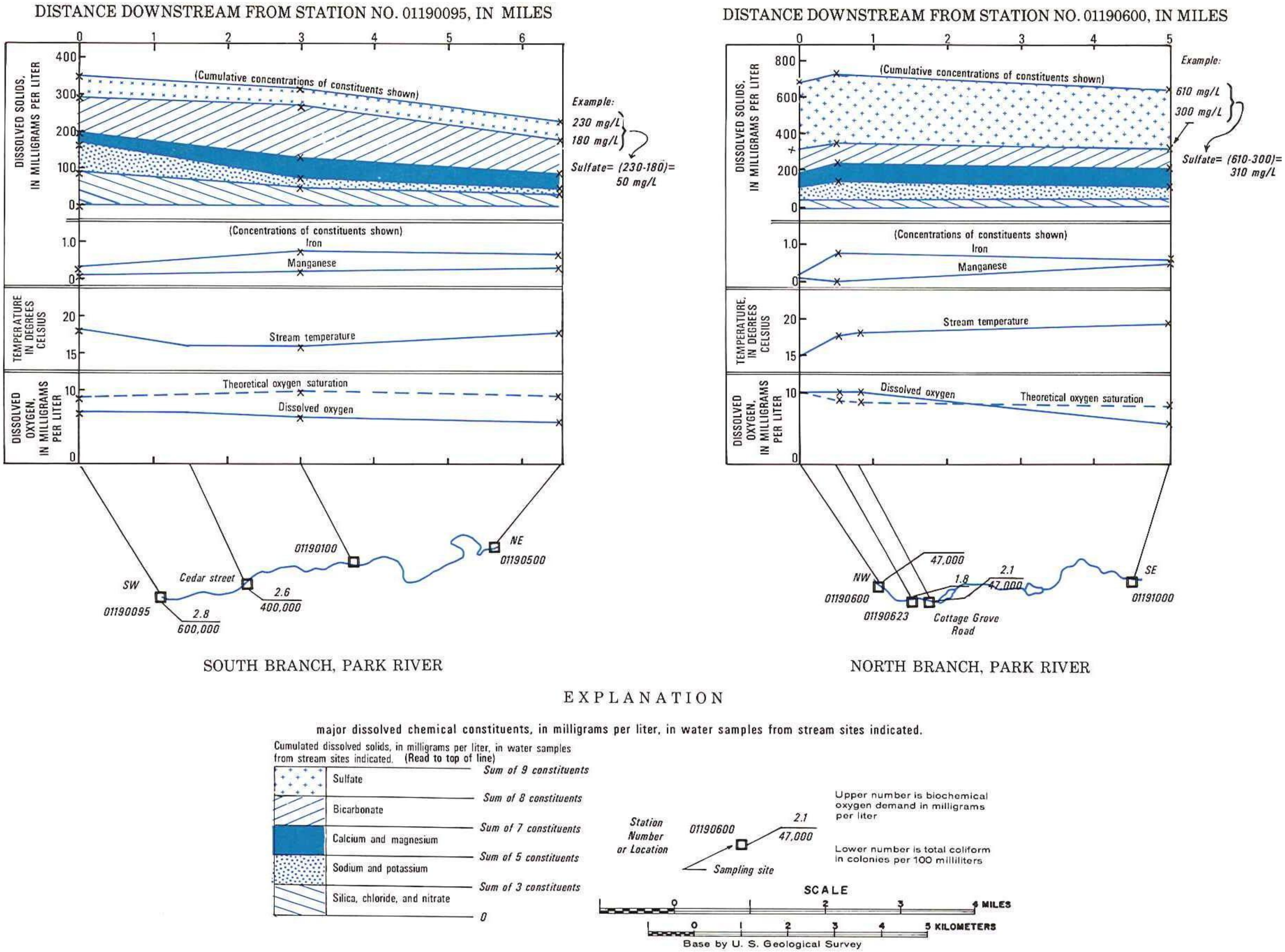


Figure 33.--Diagram showing downstream changes in quality of water in the North and South Branches of the Park River on August 13, 1968.

Table 16.--Highest nitrate and phosphate loads observed in streams in relation to predominant land use

Based on Water Resources Data for Connecticut: (U.S. Geological Survey, 1968; 1969; 1970)

TYPE OF LAND USE

Rural (non-agricultural)

Station no. (pl. A)	Stream and location	Nitrate [(lb/d)/mi²]	Phosphate [(lb/d)/mi²]
01184000	Connecticut River at Thompsonville	28	1.1
01184280	Scantic River near North Somers	19	-
01184290	Watchaug Brook near North Somers	21	-
01184300	Gillette Brook at Somers	15	-
01184400	Buckhorn Brook near Melrose	36	7.8
01184690	Dry Brook near East Windsor Hill	9	-
01191900	Charter Brook near Crystal Lake	46	-
01192200	Tankerhoosen River at Vernon Center	29	-
01192535	Porter Brook near East Hartford	12	-
01192601	Salmon Brook near Buckingham	22	-
01192640	Cold Brook near East Glastonbury	10	-
01192677	Carr Brook near Gildersleeve	5	-

Urban

Station no. (pl. A)	Stream and location	Nitrate [(lb/d)/mi²]	Phosphate [(lb/d)/mi²]
01184250	Kettle Brook at Windsor Locks	163	-
01190500	South Branch Park River at Hartford	172	-
01191000	North Branch Park River at Hartford	123	-
01192500	Hockanum River near East Hartford	119	-
01192670	Goff Brook at South Wethersfield 1/	535	17

Agricultural

Station no. (pl. A)	Stream and location	Nitrate [(lb/d)/mi²]	Phosphate [(lb/d)/mi²]
01183950	Grape Brook at Thompsonville	93	-
01184005	Stony Brook near West Suffield	421	18
01184205	Muddy Brook at Suffield	146	13
01184208	Philo Brook near Suffield	556	-
01184215	Stony Brook near Suffield	113	19
01184260	Namerick Brook near Warehouse Point	720	13
01184430	Tributary to Scantic River at Broad Brook (formerly 01184410, unnamed brook at Broad Brook)	69	19
01189995	Farmington River at Tariffville	91	-
01190002	Hathaway Hollow Brook at Poquonock	69	-
01190016	Mill Brook near Windsor	-	13
01190020	Mill Brook at Windsor	210	-
01190650	Beamans Brook at Bloomfield	365	-
01192675	Dividend Brook near Rocky Hill (formerly Dividend Brook at Goodrich Heights)	260	-

1/ Recreational use

Table 17.--Quality of water in streams affected by man
(Chemical and physical characteristics of water from three streams in the basin sampled monthly during the 1969 water year)

(Constituents in milligrams per liter (mg/L), except as noted)

Constituent or property	South Branch Park River at Hartford Station 01190500 (pl. A)			North Branch Park River at Hartford Station 01191000 (pl. A)			Hockanum River near East Hartford Station 01192500 (pl. A)			Recommended upper limit of raw water used for drinking 2/
	Median	Range	At lowest flow 1/	Median	Range	At lowest flow 1/	Median	Range	At lowest flow 1/	
Silica (SiO_2)	10	5.1-12	10	8.7	1.4-11	6.6	10	6.6-13	13	--
Iron (Fe)	1.2	.46-2.7	1.2	.37	0.9-.81	.49	.64	.12-.90	.64	--
Manganese (Mn)	.25	.2-.43	.12	.16	.01-.30	.11	.28	.08-.39	.33	--
Calcium (Ca)	40	20-44	37	42	27-99	70	26	16-31	31	--
Magnesium (Mg)	9.9	4.1-12	9.9	11	7.8-25	19	4.6	3.1-5.8	5.8	--
Sodium (Na)	3/ 30	3/ 8.5-95	3/ 45	30	11-45	31	3/ 30	3/ 16-40	3/ 37	4/ 20
Potassium (K)	5/ 1.8	1.3-2.1	--	2.2	1.2-3.9	2.7	5/ 2.8	1.8-7.6	--	--
Bicarbonate (HCO_3)	111	50-151	151	89	59-108	108	40	24-58	57	--
Sulfate (SO_4)	41	30-58	58	75	52-318	196	37	28-51	47	--
Chloride (Cl)	35	12-150	27	26	16-78	22	36	28-62	46	250
Nitrate (NO_3)	4.6	1.4-9.7	9.7	2.8	1.3-9.0	1.3	17	7.6-26	26	6/ 10
Dissolved solids (residue at 180°C)	237	107-404	278	282	155-615	403	204	118-258	258	--
Hardness as $CaCO_3$	133	67-160	133	155	100-350	253	84	53-102	102	--
Specific conductance (micromhos at 25°C)	401	195-745	457	460	258-844	631	327	205-419	416	--
pH (units)	7.3	6.6-8.1	8.1	7.4	6.8-7.9	7.9	6.6	6.4-7.3	7.3	--
Color (platinum-cobalt units)	12	5-28	28	12	4-25	6	15	10-22	22	7/ 20-250
Flow duration (percent)	--	98-10	98	--	80-15	80	--	90-15	90	--

1/ Quality of sample collected Oct. 31, 1968.
2/ Upper limit recommended by Connecticut Department of Health (Connecticut General Assembly, 1975).
3/ Contains one analysis in which sodium includes potassium (Na+K).
4/ Finished water.
5/ Based on analyses of 10 samples.
6/ Nitrite + nitrate as N.
7/ Depending on type of treatment.

sites were selected because they exhibited more than one of the controlling factors for stream temperature listed above. Solar radiation affects streams differently because of their different depths and proportions of ground-water runoff. The Scantic River and Roaring Brook (stations 01184500 and 01192650) drain rural areas and average more than 3 feet in depth for half of the year. The average daily range in temperature at these sites is 2°C. The area above the Kettle Brook station (01184250) is only slightly urbanized and averages less than 1 foot in depth for half of the year. The average daily range at the Kettle Brook site is 5°C, or more than twice that at the Scantic River and Roaring Brook. The area upstream from the Kettle Brook station is completely underlain by stratified drift, whereas only a third of the areas above the other two stations (01184500 and 01192650) are underlain by such deposits. The greater the areal extent of stratified drift in a basin, the greater the relative contribution of ground-water flow to the total flow (Thomas, 1966).

The mean stream temperature prevailing 25 percent of the time or less (winter period) was 5°C at station 01184250 and approximately 2°C at stations 01184500 and 01192650. In the winter, the ground water was warmer than the surface water, and this accounts for the higher stream temperature in Kettle Brook. The mean temperature prevailing 75 percent of the time or less (summer period) was 16°C at station 01184250 and 18°C at stations 01184500 and 01192650. In the summer, the ground water was colder than the surface water; this accounts for the colder temperature of Kettle Brook.

The temperatures of the Connecticut River, Rainbow Reservoir on the Farmington River, and the Hockanum River (stations 01184000, 01189998, and 01192500, respectively) are affected by man's activities. The Connecticut River and Rainbow Reservoir (Farmington River) are more than 5 feet deep, and less than a third of their basins are underlain by stratified drift. Many effluents, such as domestic and industrial wastes, enter these regulated streams. The flows of these two rivers, however, are large in relation to the incoming effluents, and, therefore, the effluents may have little effect on temperature. The Hockanum River, on the other hand, receives proportionately larger amounts of effluents that affect temperature. The median stream temperature at station 01192500 on the Hockanum River was 15°C, whereas the medians at the Connecticut River (station 01184000) and the Rainbow Reservoir (station 01189998) are only 9°C and 11°C, respectively.

EFFECTS OF MAN'S ACTIVITIES

The chemical and physical characteristics of three streams were measured during the 1969 water year. Specific conductance was measured continuously at three sites; one each on the North and South Branches of the Park River and the Hockanum River (stations 01191000, 01190500, and 01192500, respectively). Water samples were collected at each site and analyzed for chemical and physical constituents. For complete analyses, see Water Resources Data for Connecticut (U.S. Geological Survey, 1970). Chemical, physical, and biological constituents were determined for water samples collected from segments of the North and South Branches of the Park, the Hockanum, and the Scantic Rivers on August 13 and 14, 1968, and for the Connecticut River on June 22 and 23, 1967, and on July 5, 1967.

The North and South Branches of the Park River and the Hockanum River drain major urban areas. Simple summary statistics of the chemical and physical constituents for these three rivers are shown in table 17. The table includes a comparison of the concentration of constituents in water from the three rivers collected at low flow.

Stream profiles

North and South Branches Park River.-- The North and South Branches are the two main headwater branches of the Park River, which drains 76.2 square miles and flows eastward into the Connecticut River. Profiles of the chemical and biological constituents of these two streams are shown in figure 33. The study reach on the North Branch extends 5 miles from station 01190600 to station 01191000. The dissolved-solids concentration (residue on evaporation at 180°C) in the study reach was greater than 600 mg/L. The high dissolved solids is probably caused by highly mineralized effluents discharged into the Tumbledown Brook tributary. The iron concentration increased from 0.25 mg/L at station 01190600 on Wash Brook to 0.70 mg/L at station 01190623, directly downstream from the confluence of Wash and Tumbledown Brooks. It decreased gradually to 0.55 mg/L at station 01191000 on the North Branch of the Park River. The manganese concentration increased from 0.00 mg/L at station 01192623 to 0.40 mg/L at station 01191000. The concentration limits for iron and manganese, as recommended by the U.S. Environmental Protection Agency (1976), were both exceeded in samples from the downstream stations.

The indicators of oxidizable matter that were determined are dissolved-oxygen and biochemical oxygen demand (BOD). Total coliform bacteria colonies per 100 ml are used by the State of Connecticut as an indicator of pathogens and were also determined. The dissolved-oxygen concentration increased from 6.5 mg/L to 10 mg/L at a point 0.3 miles downstream from station 01190600 on Wash Brook at Gabb Road and then decreased to 5.5 mg/L at station 01191000 on the North Branch of the Park River. A more detailed series of oxygen measurements between station 01190600 and a point 0.8 miles downstream indicated that at station 01190623 the dissolved-oxygen concentration ranged from 10.2 to 12.7 mg/L between the hours of 0905 to 1900 e.s.t. The higher concentration is 2.5 mg/L above saturation for a temperature of 16°C and probably resulted from algal growth and respiration. The biochemical oxygen demand increased slightly from station 01190623 to a point 0.8 miles downstream from station 01190600. The total coliforms in the reach between station 01190600 and mile point 0.8 was constant at 47,000 colonies per 100 mL.

The South Branch Park River study reach extends 6.5 miles from station 01190095 on Piper Brook to station 01190500 on the South Branch of the Park River. The dissolved-solids concentration of more than 300 mg/L between stations 01190095 and 01190100 was probably caused by a combination of highly mineralized industrial-waste discharges (U.S. Department of Health, Education, and Welfare, 1964), and urban runoff from the city of New Britain to Piper Brook. The dissolved solids decreased from station 01190100 to 01190500, probably because of dilution from Mill and Trout Brooks. Iron and manganese concentrations increased from 0.3 mg/L and 0.05 mg/L, respectively, at station 01190095 to 0.70 mg/L and 0.20 mg/L at station 01190100. The increase was probably due to leaching of decayed organic matter from an intervening large swamp.

The dissolved-oxygen concentration ranged from 7.0 mg/L at station 01190095 to 6.0 mg/L at station 01190500. The dissolved-oxygen concentration in Piper Brook at Cedar Street between the hours of 0625 and 1820 e.s.t. on August 13, 1968, decreased from 7.0 mg/L to 4.6 mg/L. The total coliform bacteria ranged from 600,000 colonies per 100 mL at station 01190095 to 400,000 colonies per 100 mL at Cedar Street. These high values are probably due to the urban runoff from storm sewers. The biochemical-oxygen-demand concentration ranged from 2.8 to 2.6 mg/L between the same locations.

Hockanum River.--The Hockanum River drains 76.1 square miles and flows westward into the Connecticut River. On August 14, 1968, the dissolved-solids concentration increased from 190 to 320 mg/L between stations 01192050 and 01192055, probably as a result of effluent from the Rockville sewage-treatment plant, and decreased to 220 mg/L at station 01192500. (See figure 34.) The iron concentration decreased slightly between stations 01192055 and 01192280 and then increased to 1.0 mg/L at station 01192500, whereas manganese concentrations increased from 0.19 mg/L to 0.50 mg/L between stations 01192055 and 01192500. Many domestic and industrial effluents are added between stations 01192055 and 01192500 (U.S. Department of Health, Education, and Welfare, 1964); these could account for the additional iron and manganese. The nitrate concentration increased from 6.6 to 9.0 mg/L between stations 01192055 and 01192280 and reached 13 mg/L at station 01192500. This increase may be due to the oxidation of ammonia from sewage-treatment plants and to nitrate from fertilizers used on tobacco fields.

An analysis of minor metals in water collected at station 01192055 (U.S. Geological Survey, 1972) showed that the concentrations of cadmium and chromium were 0.07 mg/L each. These concentrations exceed the upper criteria limits set by the Connecticut Department of Health (Connecticut General Assembly, 1975) for drinking water.

Dissolved oxygen decreased from 8.0 mg/L at station 01192050 to 1.0 mg/L at Dart Hill Road, probably owing to the discharge of effluent from the Rockville sewage-treatment plant. The biochemical oxygen demand in the river directly downstream from the sewage-treatment plant was 32 mg/L; it decreased downstream to 10 mg/L at Dart Hill Road. Below Dart Hill Road, the river reaerated from a dissolved-oxygen level of 1.0 mg/L at Dart Hill Road to 6.0 mg/L at station 01192280. The total coliform bacteria increased from 150,000 at station 01192055 to 650,000 colonies per 100 mL at Dart Hill Road, probably resulting from the sewage-treatment plant. The stream temperature rose from 17° to 25°C between stations 01192050 and 01192055 and then leveled off at 24°C by station 01192500.

Scantic River.--The Scantic River drains 114 square miles north of the Hockanum River basin and east of the Connecticut River (fig. 35). The study reach extended 15 miles from Scitico (station 01184350) downstream to Cemetery Road. The dissolved-solids concentration increased from 92 mg/L at Scitico to 152 mg/L at station 01184500 at Broad Brook. This increase was probably caused in part by groundwater discharge from sedimentary rock upstream from station 01184350. However, the increase from station 01184420 to 01184500 was probably augmented by the discharge from the Broad Brook sewage-treatment plant.

The iron and manganese concentrations changed little from Scitico to Broad Brook. The nitrate, sodium, and chloride concentrations, however, increased between these stations (01184420 and 01184500), probably resulting from the discharge of effluent from the Broad Brook sewage-treatment plant.

The dissolved-oxygen concentration was barely affected by the sewage because of dilution by the Scantic River and remained above 7.0 mg/L in the study reach. Downstream from the sewage-treatment plant, the biochemical-oxygen demand decreased only slightly, from 1.5 mg/L at station 01184500 to 1.3 mg/L at Cemetery Road. The total-coliform bacteria between these stations decreased from 180,000 to 20,000 colonies per 100 mL. The higher value for total coliform was probably caused by the discharge of effluent from the sewage-treatment plant.

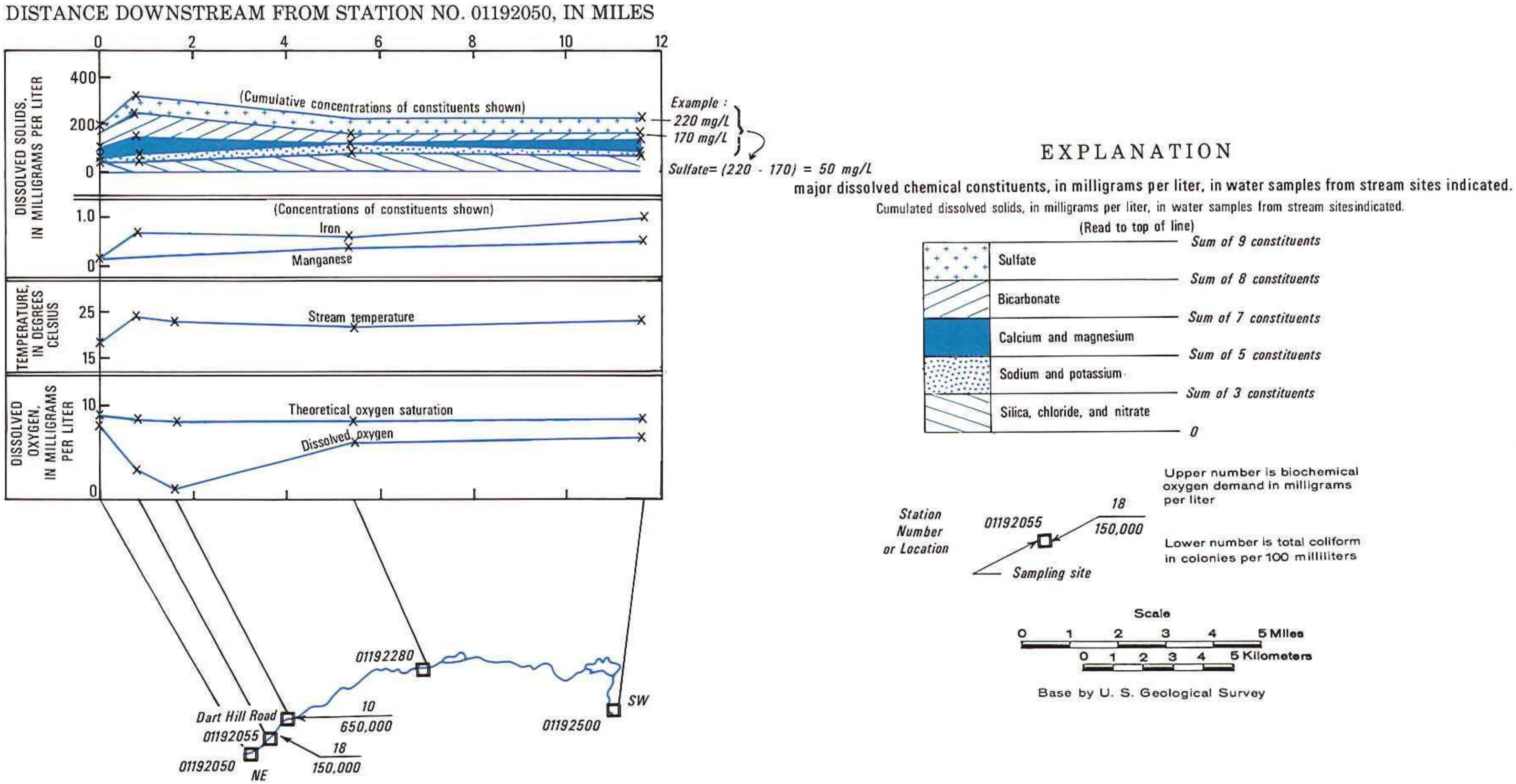


Figure 34.--Diagram showing downstream changes in quality of water in the Hockanum River on August 14, 1968.

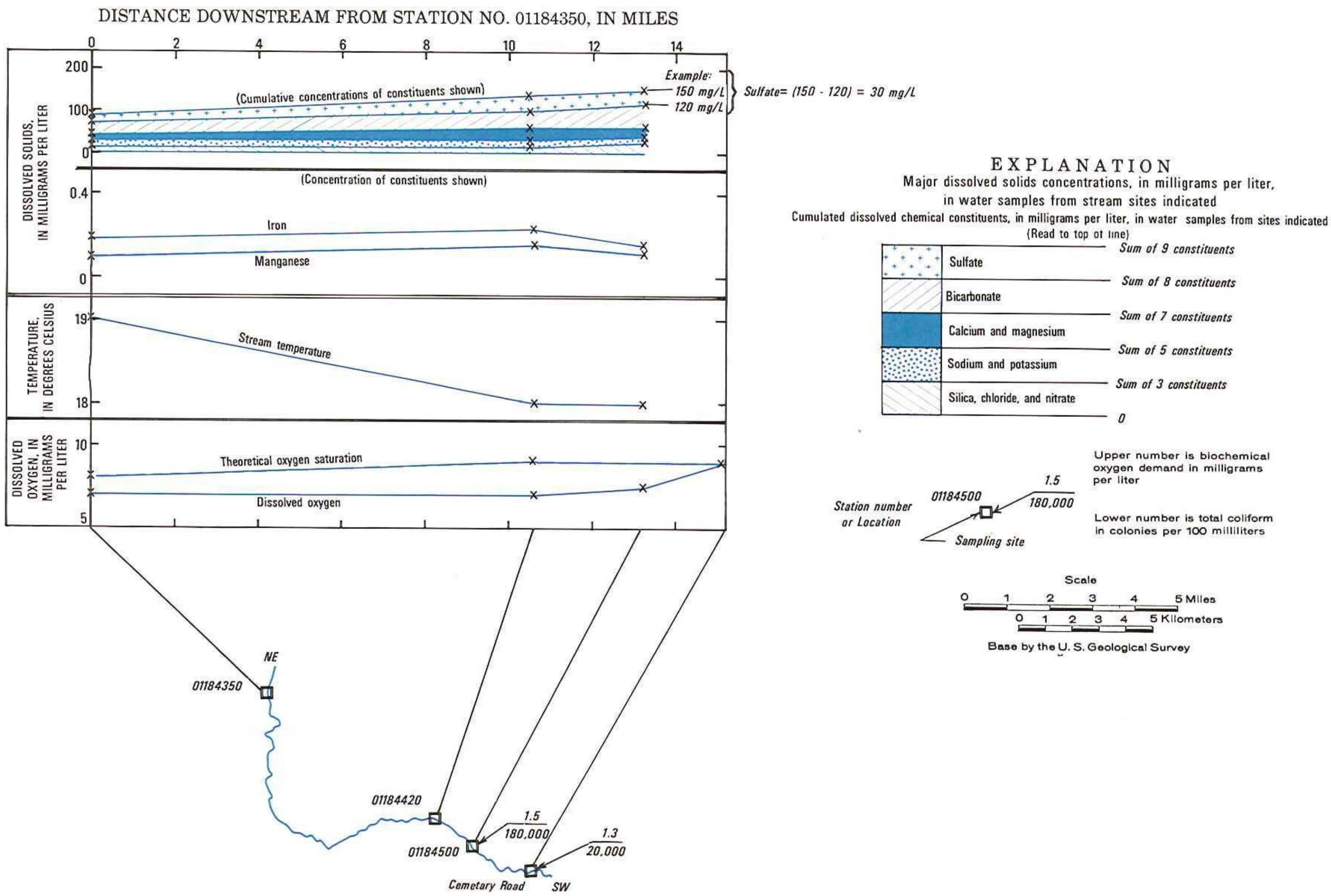


Figure 35.--Diagram showing downstream changes in quality of water in the Scantic River on August 14, 1968.

Connecticut River.--The Connecticut River drains 9,640 square miles above the Massachusetts-Connecticut State line. The study reach extends 39.5 river miles downstream from the State line to station 01193000 at Bodkin Rock (fig. 36) and drains an additional 1,115 square miles.

Water-quality data collected at sites in the study reach on June 22, June 23, and July 5, 1967 are shown in figure 36. The average discharge at station 01184000 was 18,000 ft^3/s on June 22-23 and 7,100 ft^3/s on July 5. The ranges of dissolved-solids concentrations during both sampling periods were nearly the same, from 60 mg/L at the State line to 100 mg/L at station 01192620. The dissolved-solids concentrations measured between April 5, 1967, and August 10, 1968, at various locations on the river, are shown in table 18.

During 1967-68 the iron and manganese concentrations in samples collected at streamflow greater than 70,000 ft^3/s at station 01184000 exceeded criteria limits of 0.3 mg/L for iron and 0.05 mg/L for manganese.

The maximum concentrations of sodium, chloride, and phosphate at station 01184000 during 1952-68 were 12 mg/L, 18 mg/L, and 0.83 mg/L, respectively. These high concentrations are probably the result of man's activities.

The Connecticut River is tidal downstream from station 01190027. The tides cause ponding and at some locations reverse the normal direction of river flow, as illustrated by the temperature profile for July 5, 1967. The water temperature at upstream station 01190027 was fairly constant at 22°C but it increased to 24°C at downstream station 01192629. The flow of the river at discharges less than 20,000 ft^3/s is regulated at the Vernon, Vermont and Holyoke, Massachusetts hydroelectric plants. Water is generally not impounded on weekdays but is impounded on weekends and holidays. A profile of dissolved-oxygen concentration illustrates the effect of flow regulation by the hydroelectric plant. Dissolved-oxygen concentrations on June 22 and 23 ranged from 8.0 mg/L at station 01184000 below the Enfield Dam to 5.5 mg/L in the tidal reach at station 01192910. Although the lowest concentration was in the tidal reach, the average for both the tidal and nontidal river reaches was 6.5 mg/L. The average dissolved-oxygen concentration for July 5, however, was significantly higher for tidal (11.5 mg/L) than for the nontidal reaches (8.5 mg/L). The value for the tidal section was 3.0 mg/L above saturation, suggesting the effect of phytoplankton production (respiration).

Many industrial discharges and domestic sewage plant effluents enter the Connecticut River within the study reach. The major sources of effluents are the Enfield sewage-treatment plant between the State line and station 01184000, the Windsor Locks canal between stations 01184240 and 01184255, the Hartford sewage-treatment plant between stations 01192530 and 01192620, and the Mattabesset District sewage-treatment plant between stations 01192678 and 01192910 (fig. 36). The biochemical-oxygen demand on June 22 and 23 was 3.0 mg/L at the State line but increased gradually downstream to 7.0 mg/L at station 01184700, probably as a result of sewage in inflow from the Scantic River. The concentration decreased to 4.0 mg/L at station 01190027, directly upstream from the Wilson bridge, where the river becomes tidal, then increased to 8.0 mg/L at station 01192530, immediately below the outfall of the Hartford sewage-treatment plant. The concentration also increased from 2.5 to 6.0 mg/L from a point upstream to downstream from the mouth of the Mattabesset River. The variations of the biochemical-oxygen demand in the river on July 5 were similar to those of June 22 and 23. However, the individual concentrations in the tidal reach below station 01190027 were considerably greater on July 5, probably as a result of tidal ponding and low freshwater inflow.

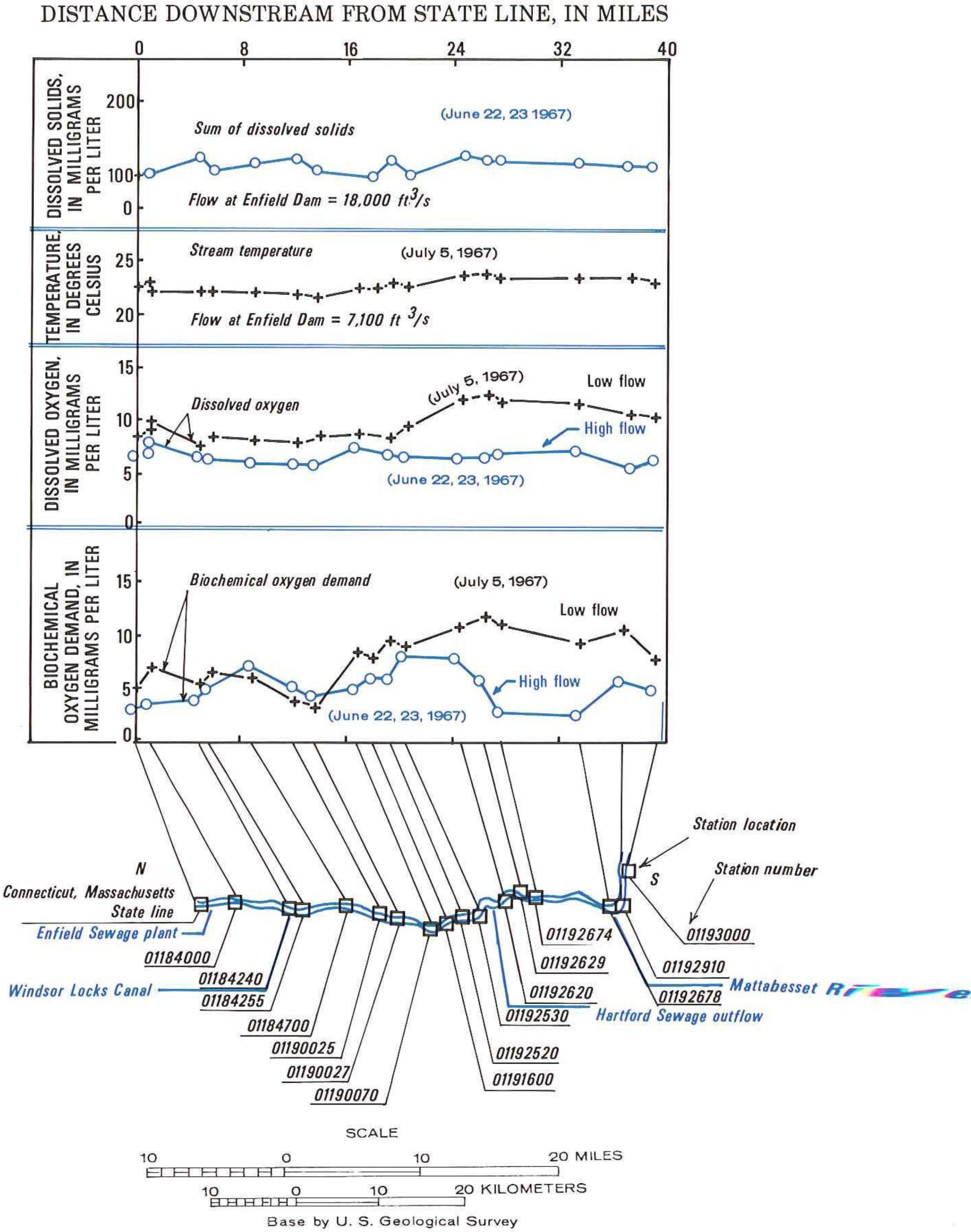


Figure 36.--Diagram showing downstream changes in quality of water in the Connecticut River during high and low flow.

LAKES, PONDS, AND RESERVOIRS

The chemical quality of water in selected lakes and reservoirs is shown in table 23. Maximum concentrations in samples of untreated water from six reservoirs and one lake that are used for water supply are: 72 mg/L, dissolved solids; 32 mg/L, hardness as calcium carbonate; 0.42 mg/L, iron; 0.20 mg/L, manganese; 20 mg/L, chloride; and 23 mg/L, nitrate.

Many lakes, ponds, and reservoirs are subject to thermal stratification during both summer and winter, and this stratification can affect some water-quality characteristics. Figure 37 shows the variation in characteristics at various depths in three impoundments. Figure 37 relates depth from the water's surface to temperature, dissolved oxygen, pH, dissolved carbon dioxide, and alkalinity in two thermally stratified water bodies and in one nonstratified water body. Contrast between summer and fall conditions is shown for thermally stratified Batterson Park Pond (fig. 37 a, b), which was formerly used as a water supply but is now used for swimming, fishing, and boating. Samples were collected at different depths along a vertical near the deepest part of each water body.

Starting in the spring, solar heat tends to stratify the water in all lakes that are deeper than light's penetration of water. An upper layer (the epilimnion) is uniformly warm, circulates, and is convective, and a deeper, colder, and less convective layer (the hypolimnion) is formed. In the boundary layer between the epilimnion and the hypolimnion (the thermocline or metalimnion), temperature changes rapidly with increasing depth ($0.3^{\circ}C/ft$).

Shenipsit Lake (fig. 37c) is 60 feet deep and stratified (Connecticut Board of Fisheries and Game, 1959). Dissolved carbon dioxide increases markedly, from 1 mg/L at the surface to 16 mg/L at 60 feet. Dissolved-oxygen concentration and pH decrease from 7.5 mg/L and 6.8 respectively, at the surface, to 0 mg/L and 5.8, respectively, at 60 feet. The decrease in dissolved oxygen with depth and the increase in carbon dioxide are probably a result of respiration and oxidation. This is typical in a stratified water body, as shown by Reid (1961, p. 150).

Buena Vista Pond (fig. 37d) is shallow, has a maximum depth of 8 feet, and has no measureable thermal stratification. The dissolved-oxygen concentration, pH, and alkalinity as calcium carbonate were fairly constant with depth. Bicarbonate ions in pH ranges of 7 to 9 constitute most of the alkalinity in the pond water.

Batterson Park Pond (fig. 37 a, b) is a thermally stratified water body that has undergone a deterioration in quality because of a change in land use. In 1941, when it supplied water to the City of Hartford, its dissolved-oxygen concentration was greater than 5 mg/L at the bottom, and its pH (6.5) was fairly constant with depth. In 1946, Batterson Park became a recreation area with increasing urbanization near the pond. By 1966, the pond was septic, having dissolved-oxygen concentrations of 0 mg/L near the bottom, a pH of 9.2 near the surface and 6.9 at a depth of 5 to 10 feet. This was probably caused by an increase in algae resulting from a possible increase in nutrients from septic systems.

GROUND-WATER QUALITY

CHEMICAL QUALITY

Dissolved solids

Previous analyses of chemical quality are supplemented by 164 analyses made for this study. Water samples were collected from 50 wells tapping coarse-grained stratified drift, 106 wells in sedimentary and igneous rocks, and 8 wells in crystalline bedrock. The results are summarized in table 19. The ranges of dissolved-solids concentrations in water from coarse-grained stratified drift, sedimentary and igneous rocks, and crystalline bedrock were 52 to 821 mg/L, 56 to 2,060 mg/L, and 58 to 256 mg/L, respectively. Figure 38 shows the areal distribution of the dissolved-solids concentration in water from bedrock wells. The figure also shows modified Stiff diagrams (Stiff, 1951), indicating the relative percentages of major chemical constituents for each well site and indicates where hardness as calcium carbonate exceeded 119 mg/L, where the sulfate concentration exceeded 249 mg/L, and where the sodium concentration exceeded 19 mg/L. Water from 106 wells in sedimentary and igneous rocks had a median dissolved-solids concentration of 202 mg/L, and water from 16 of these wells had a dissolved-solids concentration that was equal to or greater than 500 mg/L. Water from 50 wells tapping coarse-grained stratified drift included only one sample that exceeded 500 mg/L and two that exceeded 300 mg/L.

Hardness

Hardness of water is a characteristic attributed to dissolved alkaline-earth metals (principally calcium and magnesium) and is expressed as the equivalent concentration of calcium carbonate ($CaCO_3$) in milligrams per liter. Hardness of water is recognized by the

Table 18.--Quality of water in the Connecticut River
(Chemical and physical analyses of water in the reach between Thompsonville and Rocky Hill, Connecticut)
(Constituents in milligrams per liter (mg/L), except as noted)

Station no. (pl. A)	Location on Connecticut River	Date	Discharge (ft^3/s)	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 (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Phosphate (PO_4)	pH (units)	Color (platinum-cobalt units)	Specific conductance (micromhos at 25°C)	Temperature (°C)
01184000	at Thompsonville	4-12-67	53,600	4.6	0.05	0.07	9.1	1.5	5.0	0.5	20	13	6.2	0.2	0.5	56	28	12	0.07	6.7	12	83	-
		6-13-67	12,300	3.6	.06	.10	13	1.6	6.0	1.0	31	13	9.0	.3	.8	73	39	14	.43	6.6	11	112	-
		8-2-67	8,410	2.7	-	-	13	1.6	6.2	1.2	33	12	10	.2	.4	-	39	12	.46	6.5	-	116	-
		9-28-67	3,770	3.2	.19	.07	12	1.9	7.8	1.5	32	15	11	.2	1.4	88	38	12	.23	6.6	20	127	-
	1/	3-25-68	100,300	4.5	.57	.12	6.5	1.0	3.4	.9	16	10	6.4	-	.4	55	20	7	.02	6.7	7	73	1
		8-10-68	2,430	.4	.18	.14	15	2.1	5.4														
		Maximum 2/	100,300	8.5	1.4	.21	17	3.3	12	2.8	51	23	18	.6	4.3	105	53	-	.83	7.5	34	169	28
		Minimum 2/	1,750	.2	.04	.00	5.9	.8	2.7	.5	8	9.0	1.4	.0	.1	44	18	-	.00	5.9	5	57	1
01184255	at Warehouse Point	4-5-67	77,200	4.6	.46	.10	10	1.0	3.6	.9	28	12	5.0	.2	1.5	57	34	11	-	6.8	13	96	4
01190070	at Hartford	3-26-69	95,000	4.8	.77	.07	8.3	1.2	3/ 14.4	-	16	11	6.0	-	2.2	46	26	12	-	6.6	15	78	0
01192675	at Rocky Hill	7-17-67	11,100	1.4	-	-	12	1.7	7.4	1.2	28	14	12	-	1.1	70	37	14	-	7.2	10	127	24

1/ Turbidity (mg/L as silica) 5.0, dissolved oxygen 7.9 mg/L, dissolved-oxygen saturation 102 percent, total coliform bacteria 4,200 colonies per 100 milliliters (membrane filter method with immediate incubation).
2/ Based on records of analyses for the 1952-54, 1956, and 1966-68 water years.
3/ Calculated sodium plus potassium reported as sodium.

Table 19.--Chemical and physical characteristics of ground water in the upper Connecticut River basin

(Constituents in milligrams per liter, except as noted)

Aquifer			Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chlorride (Cl)	Flouride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness (as $CaCO_3$)	Methylene blue active substance (MBAS)	Specific conductance (micromhos at 25°C)	pH (units)
Coarse-grained stratified drift		Median	13	.10	.03	30	6.6	9.2	1.0	64	31	8.2	0.1	7.0	162	94	0.05	270	7.3
		Maximum	17	32	1.2	94	19	65	8.2	187	292	101	.5	86	821	486	.10	534	8.3
		Minimum	8.8	.00	.00	7.6	1.3	2.0	.5	3	8.0	.0	.0	.0	52	26	.01	71	5.0
	No. of wells sampled 1/		36	52	49	39	39	2/36	28	40	45	50	22	60	50	52	23	36	50
Sedimentary and igneous rock		Median	15	.08	.02	39	7.9	11	.8	96	37	8.4	-	3.8	202	137	.03	318	7.7
		Maximum	36	2.4	6.4	508	59	239	6.6	430	1,500	245	-	171	2,060	1,328	.25	2,150	8.5
		Minimum	3.9	.00	.00	8.8	.9	2.3	.2	14	3.4	1.1	-	.0	56	26	.00	86	6.5
	No. of wells sampled 1/		98	107	97	103	103	2/103	93	108	108	110	-	103	106	111	87	96	101
Crystalline bedrock		Maximum	23	1.1	.16	50	5.6	13	-	100	39	50	-	16	256	148	-	382	7.7
		Minimum	3.6	.02	.00	6.3	1.3	1.7	-	22	8.0	.9	-	.3	58	21	-	64	6.3
	No. of wells sampled 1/		8	8	8	8	8	3/8	-	8	8	8	-	8	8	8	-	8	8

1/ One sample from each well.

2/ Includes 8 samples with sodium and potassium calculated as sodium.

3/ Includes 6 samples with sodium and potassium calculated as sodium.

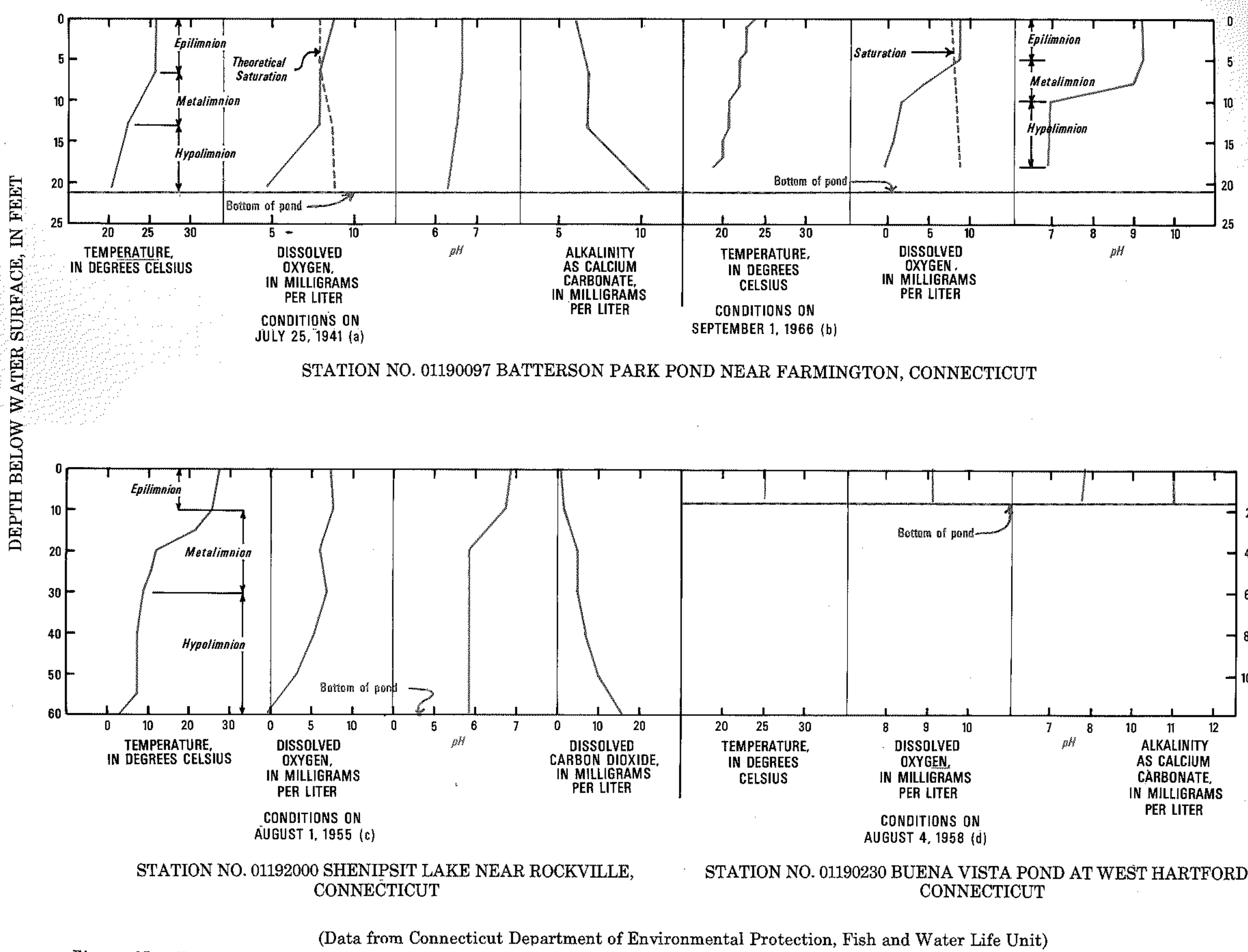


Figure 37.--Vertical profiles of summer temperature and dissolved constituents in three ponds in the upper Connecticut River basin.

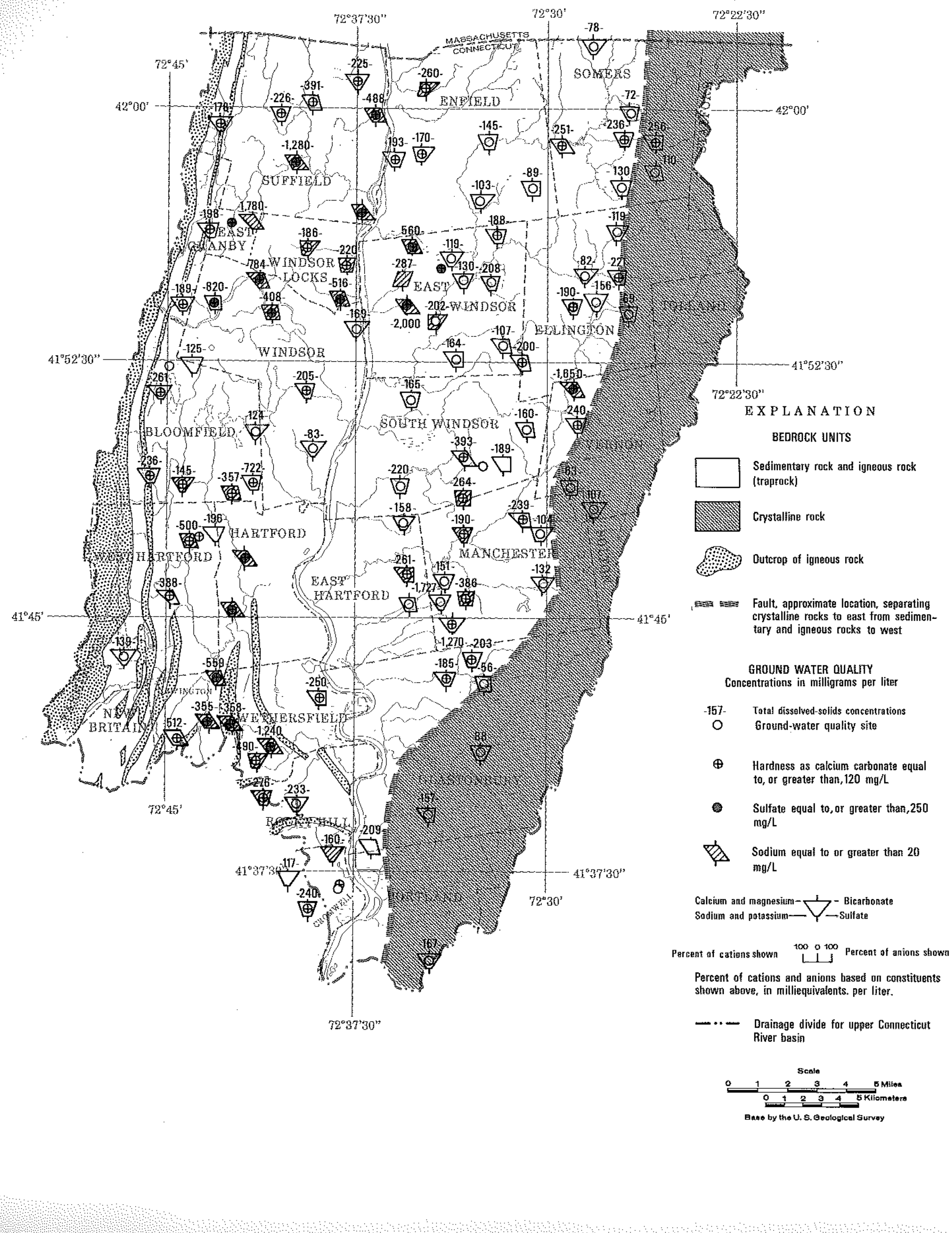


Figure 38.--Map showing chemical quality of ground water from bedrock.

large quantity of soap required to produce a lather and is approximately equal to the amount of dissolved alkaline earth that precipitates from water upon boiling. This is carbonate or temporary hardness. That part of the "total" hardness remaining in water after boiling is noncarbonate or permanent hardness. The following classification for hardness is used by the U.S. Geological Survey:

Hardness as $CaCO_3$ (mg/L)	Descriptive rating	Suitability and treatment[a/]
Less than 60	Soft	Suitable for most purposes without softening.
6-120	Moderately hard	Usable without treatment except in some industrial applications.
121-180	Hard	Softening required by laundries and some industries.
Greater than 180	Very hard	Softening required for almost all uses.

a/ Methods of softening water are discussed by Wilke and Hutcheson (1962).

As shown in table 19, the median hardness of water from 52 wells tapping coarse-grained stratified drift was 94 mg/L, and that from 111 wells tapping sedimentary and igneous rocks was 137 mg/L. Approximately 60 percent of the samples of water from the 111 wells in sedimentary rocks had a hardness greater than 120 mg/L, and in approximately 30 percent of these same samples, the noncarbonate hardness was greater than the carbonate hardness. The main source of carbonate hardness is probably calcite, which occurs as a constituent mineral and cementing agent in the sedimentary rock (Krynine, 1950, p. 84). The source of the noncarbonate hardness is secondary minerals, such as calcium and sodium sulfate.

Figure 39 shows the ratios of calcium to sulfate and sodium to sulfate in water samples from 57 wells tapping sedimentary rocks. The diagram indicates that these ratios are relatively constant where the dissolved-solids concentration exceeds about 300 mg/L (hard-water areas). This suggests that in such areas the concentrations of calcium and sodium are directly related to that of sulfate and indicates that secondary minerals, such as gypsum ($CaSO_4 \cdot 2H_2O$), are contributing to hardness.

The hardness of water and thickness of bedrock penetrated by each of 147 wells in sedimentary and igneous rocks is shown on figure 40. The figure also shows areas where water from sedimentary rock can be expected to have hardness concentrations greater than 120 mg/L as $CaCO_3$, in relation to thickness of bedrock penetrated. In area A (west of the Connecticut River), the water was harder than 120 mg/L, regardless of the thickness of bedrock penetrated. In areas B (west) and C (east of the Connecticut River) water was harder or softer than 120 mg/L, depending on the thickness of bedrock penetrated. In area B, water from 76 percent of the shallow wells (less than 100 feet of bedrock penetrated) was harder than 120 mg/L. In area C, water from 72 percent of the wells penetrating less than 100 feet of bedrock was harder than or equal to 120 mg/L, but water from only 58 percent of the wells exceeded this level where more than 200 feet of sedimentary rock was penetrated. The water from sedimentary rock in area B gets harder with thickness of bedrock penetrated, whereas, in area C, the water gets softer with thickness of rock penetrated, for depths less than 900 feet.

Sulfate

Sulfate is a major constituent of the water from sedimentary rock. Its sources in ground water are air-borne particles in rainfall and earth materials containing gypsum and pyrite. The wells in sedimentary rock that yielded water containing 250 mg/L or more of sulfate are shown in figure 38. Of the 108 wells sampled, 17 yielded water containing 250 mg/L or more. The median concentration was 37 mg/L, with a range of 3.4 to 1,500 mg/L. Pyrite (FeS_2) is reported to be a common iron mineral in these rocks (Krynine, 1950, p. 26), but gypsum is probably also a constituent, according to Abel (Krynine, 1950, p. 168). Figure 39 indicates that the solution of gypsum ($CaSO_4 \cdot 2H_2O$) may be the primary cause of high concentrations of sulfate in water from sedimentary rock, particularly where the dissolved-solids concentrations exceed 300 mg/L.

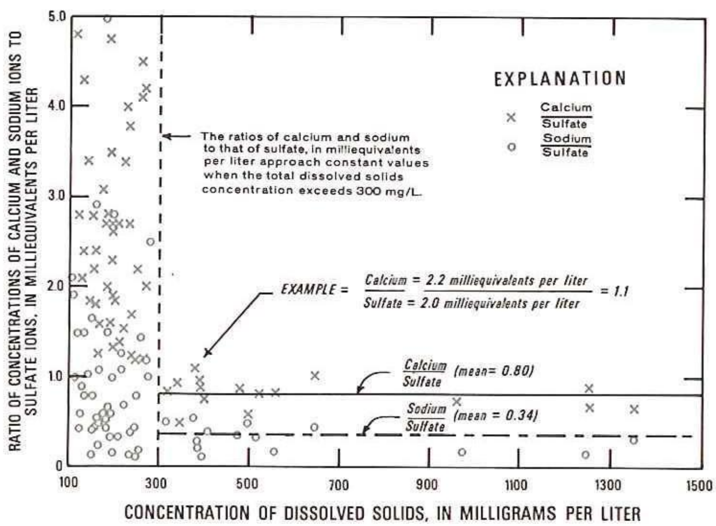


Figure 39.--Graph showing the ratios of calcium to sulfate and of sodium to sulfate in relation to dissovled-solids concentration in water from sedimentary bedrock.

Table 20.--Iron and manganese in ground water

(Concentrations in milligrams per liter)

Constituent		Type of aquifer: Coarse-grained stratified drift	Sedimentary and igneous rock
Iron	Median	0.10	0.08
	No. of wells sampled	52	107
	No. exceeding 0.3 mg/L	8	19
Manganese	Median	.03	.02
	No. of wells sampled	49	97
	No. exceeding 0.05 mg/L	21	19

Sodium

Sodium is leached from earth materials. Subsurface water can receive additional amounts from backflushing of water softeners, runoff containing road salts, and runoff from fertilized agricultural areas. The median concentration of sodium in water samples from 36 wells tapping coarse-grained stratified drift was 9.2 mg/L, with a range from 2.0 to 65 mg/L. The Connecticut Department of Health (Connecticut General Assembly, 1975) recommends an upper limit of 20 mg/L in drinking water. Water from only four of the wells sampled exceeded this limit.

The median concentration of sodium in water samples from 103 wells tapping sedimentary rock was 11 mg/L, and the range was from 2.3 to 239 mg/L. Of the 103 wells, water from 31 had sodium concentrations greater than 20 mg/L. Figure 38 shows the location of all bedrock wells sampled. As previously indicated, figure 39 suggests that the concentration of sodium is directly related to that of sulfate in water from sedimentary rock.

Iron and manganese

The possible sources of iron and manganese in ground water are iron and manganese oxides and iron sulfide.

Figure 29 shows the areal distribution of these constituents in water from coarse-grained stratified drift and from bedrock. It shows the areas where iron and manganese concentrations exceeded 0.3 mg/L and 0.05 mg/L, respectively. Most of the wells in sedimentary and igneous rocks that yielded water containing concentrations above these recommended limits (U.S. Environmental Protection Agency, 1976) are west of the Connecticut River.

The median concentrations of iron and manganese in water from wells tapping coarse-grained stratified drift and sedimentary and igneous rock is shown in table 20. Iron concentrations exceed the recommended limits in 15 percent of the samples from each aquifer. Manganese concentrations exceed the limits in 43 percent of the samples from stratified drift and 20 percent of the samples from sedimentary and igneous rock. Both constituents can be removed from water by treatment if individual concentrations do not exceed 2 or 3 mg/L (Wilke and Hutcheson, 1963).

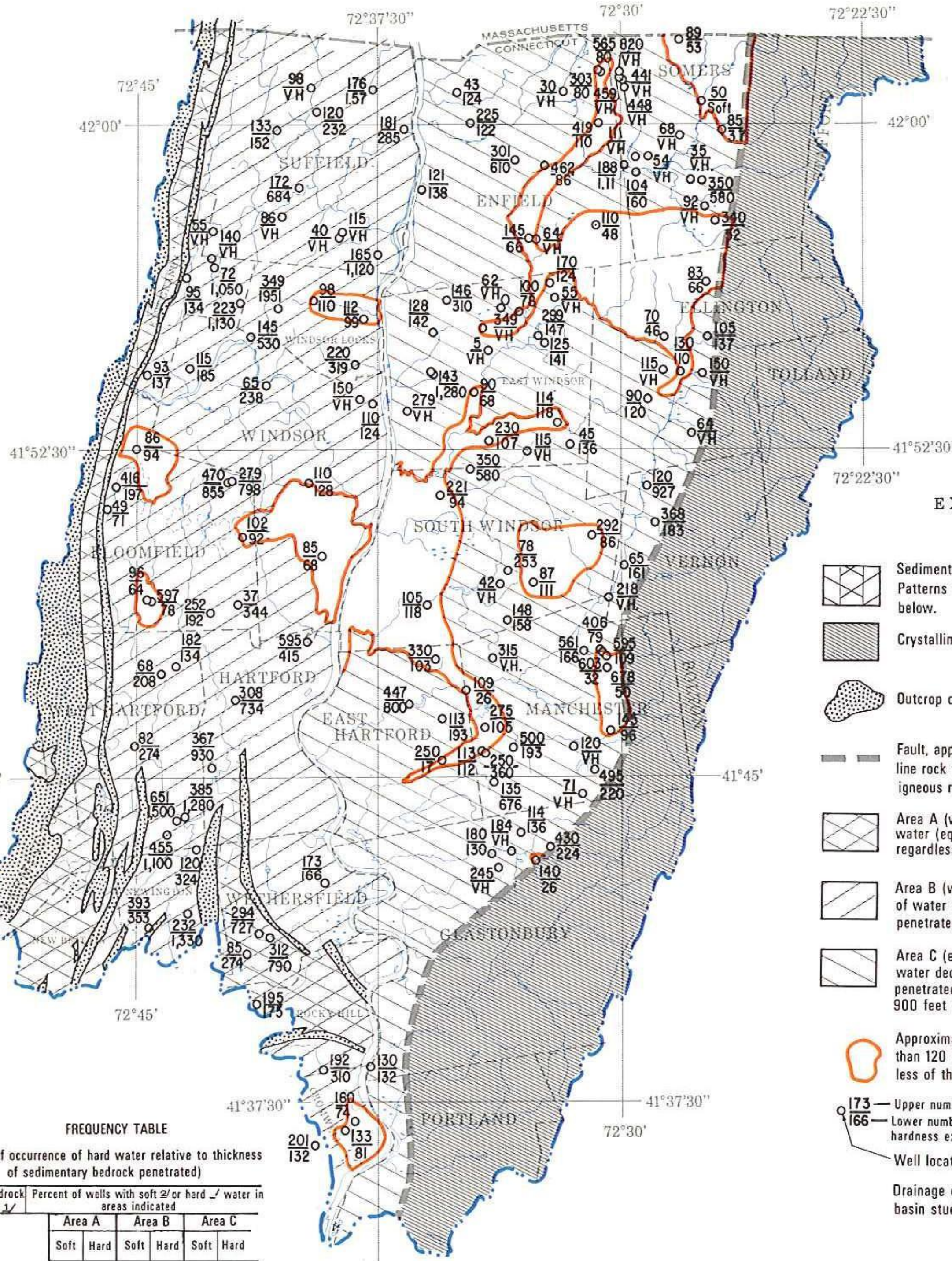
Nitrate

Dissolved nitrate is a major nutrient for vegetation. It occurs naturally in aquifers recharged by rain and also results from bacterial action in the soil. Nitrate may be added to water when fertilizers are used and when animal or domestic wastes leach into ground water (Hem, 1970, p. 182). The median nitrate concentration of water from 60 wells tapping coarse-grained stratified drift was 7.0 mg/L, and the range was from 0 to 86 mg/L. The median concentration in water from 103 wells tapping sedimentary and igneous rocks was 3.8 mg/L, with a range of 0.0 to 171 mg/L.

Table 21 suggests that the nitrate concentrations in ground water are related to the thickness of unconsolidated deposits, well-construction characteristics, and surface contamination. For example, the median nitrate concentration in water from 44 wells penetrating less than 75 feet of unconsolidated deposits was 9.2 mg/L, whereas in water from 16 wells penetrating 75 feet or more of these deposits, it was 3.4 mg/L. Casing set into bedrock gives protection from surface contamination. Where unconsolidated deposits are more than 50 feet thick and the casing is set more than 5 feet into bedrock, the frequency of high nitrate concentrations was lower and indicated a greater degree of protection from surface contamination. Only four wells, all tapping less than 75 feet of unconsolidated deposits, yielded water that exceeded the Connecticut Department of Health (Connecticut General Assembly, 1975) limit of 10 mg/L nitrate plus nitrite as N. All wells sampled were in nonsewered areas.

Chloride

Chloride in local ground water rarely exceeds 10 mg/L unless it has been added by sewage, dissolution of road salt, or backflushing of water softeners. The median concentration of chloride in water from 50 wells tapping coarse-grained stratified drift was 8.2 mg/L, and that from 110 wells in sedimentary and igneous rocks was 8.4 mg/L. The chloride range in water from 50 wells in stratified-drift was 0.0 to 101 mg/L, whereas the range in water from 110 wells tapping sedimentary and igneous rocks was 1.1 to 245 mg/L. Twenty six of the 50, and 57 of the 110 wells yielded water with chloride concentrations greater



EXPLANATION

Sedimentary rock and igneous rock (traprock): Patterns indicate areas A, B, and C as noted below.

Crystalline rock

Outcrop of igneous rock

Fault, approximate location, separating crystalline rock to east from sedimentary rock and igneous rock to west

Area A (western margin of study area) hard water (equal to or greater than 120 mg/L) regardless of thickness of bedrock penetrated.

Area B (west of Connecticut River) hardness of water increases with thickness of bedrock penetrated (see frequency table)

Area C (east of Connecticut River) hardness of water decreases with thickness of bedrock penetrated for bedrock penetration less than 900 feet (see frequency table).

Approximate areal extent of soft water (less than 120 mg/L) from sedimentary rock regardless of thickness of bedrock penetrated

173 — Upper number is length of bedrock penetrated in feet
166 — Lower number is hardness, in mg/L VH indicates hardness exceeds 180 mg/L
Well location

Drainage divide for upper Connecticut River basin study area

Scale: 0 1 2 3 4 5 Miles; 0 1 2 3 4 5 Kilometers

Base by the U. S. Geological Survey

FREQUENCY TABLE

(Frequency of occurrence of hard water relative to thickness of sedimentary bedrock penetrated)

Thickness of bedrock penetrated 1/	Percent of wells with soft 2/ or hard 3/ water in areas indicated					
	Area A		Area B		Area C	
	Soft	Hard	Soft	Hard	Soft	Hard
less than 100 ft	0	100	24	76	28	72
100 to 200 ft	0	100	17	83	30	70
more than 200 ft and less than 900 ft	0	100	6	94	42	58
number of wells	16		54		89	

1/ Rounded to nearest foot 2/ less than 120 mg/L hardness

3/ equal to or greater than 120 mg/L hardness (includes very hard water)

Figure 40.--Map showing relation of hardness of water from sedimentary rock to thickness of bedrock penetrated.

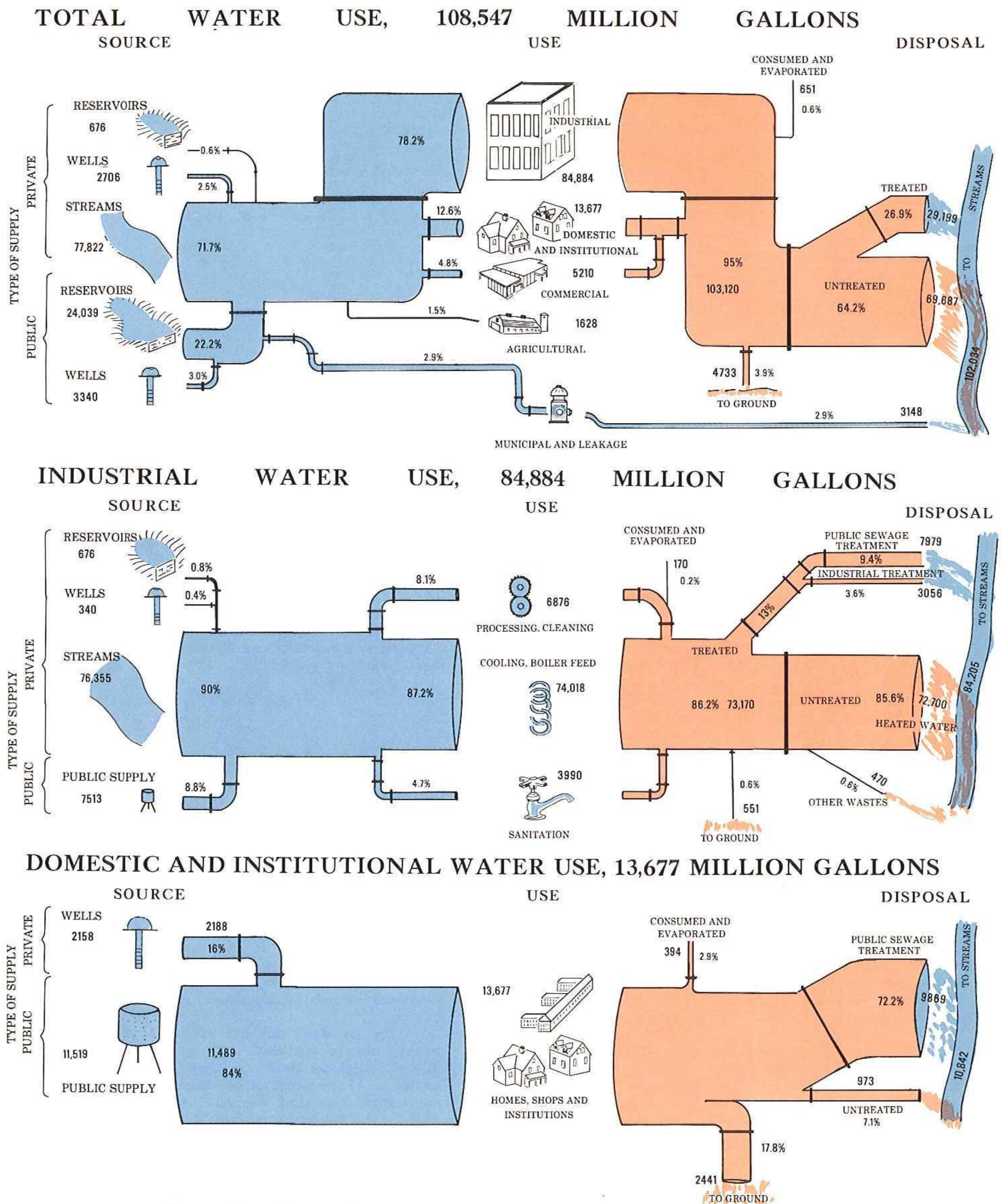


Figure 41.--Diagram showing source, use, and disposal of water in the upper Connecticut River basin, 1968.

All quantities are in millions of gallons.

Table 21.--Nitrate in ground water

(Nitrate concentration is related to thickness of unconsolidated deposits and well construction practices)

Nitrate concentration equal to or greater than	Wells in unconsolidated deposits: Length of casing is Less than 75 ft	Equal to or greater than 75 ft 1/	Equal to or greater than 100 ft	Wells in bedrock: Casing less than 5 ft into bedrock: Thickness of unconsolidated deposits cased off is Less than 50 ft	Equal to or greater than 50 ft	Casing equal to or greater than 5 ft into bedrock: Less than 50 ft	Equal to or greater than 50 ft
	Percent of wells			Percent of wells			
5 mg/L	77	50	29	56	46	60	14
10 mg/L	48	31	14	56	33	50	14
20 mg/L	27	6	0	44	16	18	7
45 mg/L	9	0	0	0	0	0	0
Number of wells	44	16	7	28	28	25	30

1/ Includes lengths of casing greater than 100 ft.

than 10 mg/L, but none had concentrations exceeding the Connecticut Department of Health (Connecticut General Assembly, 1975) recommended upper limit for drinking water of 250 mg/L.

Detergents

The major indicator of detergent contamination in ground water before 1965 was alkylbenzenesulfonate (ABS), which was reported in terms of the concentration of methylene-blue active substances (MBAS) in milligrams per liter. ABS is a persistent nondegradable substance. Beginning in mid-1965, ABS was gradually replaced by linear alkylatesulfonate (LAS), also reported as MBAS, which is more degradable than ABS under similar conditions. The Connecticut Department of Health (Connecticut General Assembly, 1975) has set an upper limit of 0.5 mg/L for MBAS in drinking water. The median concentration of detergents as MBAS in water from 23 wells tapping coarse-grained stratified drift was 0.05 mg/L, with a range from 0.01 to 0.10 mg/L. The median concentration of detergents as MBAS in water from 87 wells tapping sedimentary and igneous rocks was 0.03 mg/L, with a range from 0.00 to 0.25 mg/L.

USE OF WATER IN 1968

The total amount of water used in the basin in 1968 was 108,547 million gallons. Excluding water used by industry, institutions, and commercial establishments, the domestic use from urban supplies ranged from 41 to 72 gallons per capita per day, and that from rural supplies ranged from 46 to 104 gallons per capita per day. The average domestic use was 84 gallons per capita per day. Of the water used for domestic purposes, 84 percent was supplied by 15 major public-owned companies and municipalities and 25 private associations.

The source, use, and disposal of water in 1968 are shown in figure 41. The locations, amounts, and type of major withdrawals and returns are shown on plate D. The plate also shows areas served by sewer systems and the points at which used water is returned to streams and to the ground. Table 22 shows the source of water, capacity and type of treatment, and population served for selected water-supply systems. The industrial water use in 1968 was 84,884 million gallons, of which only 8.8 percent was supplied by public systems. Industry used 78 percent of all the water supplied during the 1968 calendar year. The major use of water by industry was for cooling, and 90 percent of the industrial water came from surface-water sources. The municipality of New Britain diverts 1.8 billion gallons from the Farmington, Quinnipiac, and Mattabesset River basins into the upper Connecticut study area. The Metropolitan District Commission imports 19.4 billion gallons from the Farmington River basin. These latter two diversions accounted for 20 percent of the total water used during 1968, or 78 percent of the total supplied by public supplies in the basin.

The chemical quality of water from 13 public-supply systems, each serving at least 300 persons, is shown on table 23. The raw water in these systems had dissolved-solids concentrations that ranged from 32 to 326 mg/L. The hardness ranged from 11 to 185 mg/L. Manganese was the only constituent in the raw water of six water supplies exceeding the concentration limits suggested by the U.S. Environmental Protection Agency (1976) for drinking water. The iron concentration in the raw water samples exceeded the recommended limits in four samples from four supplies, and the nitrate concentration in the raw water samples exceeded those limits in only one of the samples.

Table 22.--Characteristics of principal public water-supply systems serving the upper Connecticut River basin

(Based on estimates and records for 1968 from water-utility officials)

Public water-supply system	Town(s) supplied	Total population served	Primary source of water: Name of source	Primary source of water: Percent of supply	Auxiliary or emergency sources	Treatment: Type(s) used in system	Treatment: Name or location of plant	Treatment: Capacity (Mgal/d)	Raw water storage (million gallons)	Finished water storage (million gallons)	Total supplied in 1968 (million gallons)	Use of water (percent): Domestic	Use of water (percent): Commercial	Use of water (percent): Industrial	Use of water (percent): Municipal and leakage	Remarks
Avery Heights Water Co.	South Windsor	1,000	Well	100	Manchester Water Company	Chlorine and calgon	Avery Road, South Windsor	--	None	None	33	100				
Bradley Field, State Dept. of Aeronautics	Windsor Locks	12,000	Wells	100	None	Chlorine	Bradley Field	--	None	None	183		100			
Broad Brook Water Co.	East Windsor Somers	1,932	Broad Brook Well Keery Well Ellis Well Fuller Hurd Well Preston Wells	60.8 .0 2.8 11.2 25.2	Well	Chlorine	East Windsor Somers Somers	--	None	0.1	53.6	1/ 60.6		17.3	22.1	1/ Domestic and commercial.
Burnham Acres Assoc.	South Windsor	125	Wells	100	None	None	None	--	None	None	3.7	100				
Carlson, S., Inc.	Glastonbury	20	Spring	100	None	None	None	--	None	None	.7	100				
Chestnut Heights	Suffield	50	Wells	100	None	Filtration 2/	Suffield	--	None	None	1.1	100				2/ Well number one untreated.
Chestnut Hill Heights Water Assoc.	Glastonbury	32	Well	100	None	None	None	--	None	None	1.1	100				
Connecticut State Prison	Enfield	1,200	Wells	100	Well	Chlorine and softening	Enfield	--	None	None	83.1				100	
Connecticut Water Co., Northern Div.	East Windsor South Windsor Suffield Thompsonville Vernon West Suffield Windsor Locks	44,260	Mapleton Well Spring Well Waterworks Wells Windsor Locks Wells Rockville Water System Hunts Wells	3.3 48.8 14.5 28.2 5.2	West Suffield Wells Farnam Estate Wells Woodland Park Wells	Chlorine 3/ Fluoride 4/ Softening 5/	Suffield Thompsonville Windsor Locks Rockville East Windsor	--	None	None	1,799	47.9		6/34.8	17.3	3/ All wells. 4/ Only at Spring Lots, Hunts, and Mapleton. 5/ Only at Farnum Estate. 6/ Commercial and industrial.
Cromwell Fire District	Cromwell	7/3,200	Dividend Wells Nooks Pond	73.9 26.1	Ice House Pond Shanty Pond Cromwell Reservoir Wells	Chlorine and fluoride	Cromwell	9.3	9.3	1.2	8/117	56.4	42.6	.3	.7	7/ Population served in basin. 8/ Based on population served in basin.
Campbell, E. J.	Vernon	120	Well	100	None	None	None	--	None	None	3.3	100				
Ellington Acres	Ellington	105	Well	None	None	None	None	--	None	None	2.9	100				
Ellington Water Co.	Ellington	300	Well	100	None	None	None	--	None	5.0	8.4	89	11			
Ellsworth Acres	East Windsor	60	Well	100	None	None	None	--	None	None	1.8	100				
Ferncliff	West Hartford	112	Well	100	None	None	None	--	None	None	3.1	100				
Grant Hill Assoc., Inc.	Bloomfield	175	Well	100	None	None	None	--	None	None	4.4	100				
Hazardville Water Co.	Enfield	14,256	Town Farm Well South Maple Well Bucken Road Well Queen Street Wells Grant Road Well Scitico Wells Oak Street Well	16.4 7.7 4.7 45.4 4.9 15.4 5.5	None	Clorine 9/	Hazardville	--	None	0.8	439		1/84.3	4.2	11.5	9/ Only Queen Street, Town Farm, and Scitico Wells are treated.
Hathewood	Farmington	100	Well	100	None	None	None	--	None	None	2.9	100				
Hilltop, Inc.	Farmington	125	Well	100	None	None	None	--	None	None	3.3	100				

Table 22.--Characteristics of principal public water-supply systems serving the upper Connecticut River basin.--Continued

(Based on estimates and records for 1968 from water-utility officials)

Public water-supply system	Town(s) supplied	Total population served	Primary source of water: Name of source	Primary source of water: Percent of supply	Auxiliary or emergency sources	Treatment: Type(s) used in system	Treatment: Name or location of plant	Treatment: Capacity (Mgal/d)	Raw water storage (million gallons)	Finished water storage (million gallons)	Total supplied in 1968 (million gallons)	Use of water (percent): Domestic	Use of water (percent): Commercial	Use of water (percent): Industrial	Use of water (percent): Municipal and leakage	Remarks
Manchester Water Co.	North Manchester	14,900	Reservoirs Wells	61.6 38.4	Risley Reservoir	Chlorine and calgon	None	--	87.5	None	464	48.7	3.6	1.2	10/46.5	10/ Includes water unaccounted for.
Manchester, City of, Water Dept.	Manchester Glastonbury	27,350 650	Howard Reservoir Porter Reservoir Globe Hollow Res. Buckingham Res. Charter Oak Wells Love Lane Well	 79.3 18.3 2.4	Fern Street Well	Aeration, coagulation, alum, soda ash, chlorine, sedimentation, filtration, calgon, lime, and fluoride 11/	Cooper Hill, Line Street, Manchester	2.0 1.5	479	2.8	1,508	48.6	6/14.1		12/37.3	11/ Water from Howard and Porter Reservoirs and Charter Oak Wells has chlorine, fluoride, calgon, and lime treatment; Love Lane well has chlorine. Globe Hollow and Buckingham Reservoirs have chlorine, fluorine, alum, soda ash treatment, and processes such as sedimentation, coagulation, aeration, and filtration. 12/ Includes large leakage.
Maple Ridge Farms	Farmington	140	Well	100	None	None	None	--	None	None	4.0	100				
Metropolitan Dist. Comm.	Bloomfield East Hartford Farmington Glastonbury Hartford Newington Rocky Hill South Windsor West Hartford Wethersfield Windsor	7/365,590	Nepaug Reservoir Barkhamsted Reservoir West Hartford Reservoir #5	47.8 48.4 3.8	West Hartford Reservoirs #2, #3, and #6 Cold Brook Res. West Branch Reservoir Colebrook Reservoir	Aeration, slow sand filtration, chlorine, lime, calgon, and fluoride 13/	Farmington Ave., West Hartford	62.5	57,650	33.3	19,444	39.4	24.1	30.6	5.9	13/ Cold Brook Reservoir treated by sedimentation and chlorine.
Neipsic Woods Section #3	Glastonbury	40	Wells	100	None	None	None	--	None	None	1.1	100				
Neipsic Woods Water Assoc.	Glastonbury	72	Wells	100	None	None	None	--	None	None	1.8	100				
New Britain, City of, Water Dept.	Farmington New Britain Newington	7/50,577	Coppermine Brook Panther Swamp Reservoir Shuttle Meadow Reservoir 14/ Whigville Reservoir Whites Bridge Wells Wolcott Res.	0.0 35.5 17.9 19.5	Nepaug Res. 15/	Aeration, coagulation, lime, soda ash, chlorine, sedimentation, rapid sand filtration, fluoride, and activated carbon 16/	Reservoir Road, New Britain	15	2,359	8.9	1,860	1/ 460		37.5	16.5	14/ Panther Swamp and Shuttle Meadow Reservoirs. 15/ Raw water pipeline to Whigville Reservoir transmission line. 16/ Whigville Reservoir has only chlorine, and Whites Bridge wells have chlorine and fluoride treatment.
Oakwood, Inc.	Glastonbury	64	Wells	100	None	None	None	--	None	None	1.8	100				
Pine Knob Hill	South Windsor Vernon	580	Well	100	None	None	None	--	None	10	15.3	100				
Portland Water Works	Portland	7/ 4,500	Portland Res. Well	94.7 5.3	None	Chlorine and calgon	None	--	150	1.5	8/199	65.4	18.4	12.6	3.6	
Quonnock Hollow Water Assoc.	Suffield	16	Well	100	None	Chlorine	None	--	None	None	.4	100				
Rockville Water and Aqueduct Co.	Ellington Rockville	13,688	Shenipsit Lake	100	None	Chlorine, calgon, and lime	None	--	4,697	1.5	1,023	1/ 40.2		17.4	12/42.4	
Rolling Hills Development	Glastonbury	175	Well	100	None	None	None	--	None	None	4.4	100				
School Hill Assoc.	Broad Brook	125	Well	100	None	None	None	--	None	None	3.3	100				
Shaker Heights, Inc.	Enfield	185	Well	100	None	None	None	--	None	None	4.8	100				
S.H.V.C., Inc.	Manchester	20	Spring	100	None	None	None	--	None	None	.6	100				
Somersville Manufacturing	Somersville	110	Well	100	None	None	None	--	None	None	5.1	50	50			
Talcottville Water Co.	Talcottville	360	Well	100	Well	None	None	--	None	.05	14.6	94	6			
Vernon Water Company	Vernon	3,000	Wells	100	Ponds	Chlorine	None	--	.08	None	54.1	89.4	10.2	.4		
Windsorville Water Assoc.	East Windsor	64	Well	100	None	None	None	--	None	None	1.8	100				
Woolam Farm	East Windsor	30	Well	100	None	None	None	--	None	None	.7	100				

Table 23.--Chemical and physical quality of water from principal public water-supply systems in the upper Connecticut River basin

(Constituents in milligrams per liter, except as noted)

Public water-supply system	Date of collection	Source F, finished water R, raw water	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)	Nitrite (NO_2)	Phosphate (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$ Calcium, magnesium	Noncarbonate	Specific conductance (micromhos at 25°C)	Temperature (°C)	pH (units)	Color (platinum-cobalt units)	Methylene blue active substances (MBAS)
Recommended upper limit in raw water used for drinking 1/			-	-	-	-	-	2/ 20	-	-	-	250	2.0	3/ 10	-	-	500	-	-	-	-	-	4/ 20-250	0.5
Avery Heights Water Co.	4-29-68	R Well SW 112	15	0.03	0.01	32	7.0	16	2.0	56	43	31	0.1	20	-	-	200	109	63	320	12	6.7	4	.06
Broad Brook Water Co.	5-12-69	R Well EW 50	15	.07	.00	45	7.2	7.7	.7	96	54	8.4	-	14	0.03	-	198	142	63	311	12	7.8	-	.05
	5-12-69	R Fuller Hurd Well SO 71	12	.12	.00	41	10	13	1.1	94	18	48	-	12	.02	-	236	143	66	366	12	7.8	-	.04
	5-12-69	R Preston Wells SO 84	16	.17	.00	17	3.7	8.7	.7	22	15	-	-	15	.02	-	122	58	40	179	10	7.0	-	.03
	5-12-69	R Ellis Well SO 85	16	.05	.00	50	5.6	13	2.2	74	39	50	-	9	.03	-	256	148	88	382	13	7.3	-	.04
Connecticut Water Co., Northern Division	2-14-68	R Well EW 88	16	.05	.02	33	9.3	5/ 9.2	-	106	30	16	-	.2	-	-	170	120	34	280	11	7.3	-	-
	5-23-68	R Well EW 90	16	.23	.34	31	7.4	7.3	.5	82	33	12	.1	5.0	-	-	162	108	41	250	-	7.1	7	.07
	5-12-69	R Well EW 90	13	2.2	.57	40	8.3	8.8	.7	80	58	12	-	15	.41	-	198	134	68	310	11	7.8	-	.04
	5-12-69	R Hunt Well EW 103	13	.06	.04	54	9.4	16	1.0	121	98	7.3	-	.0	.01	-	262	173	74	395	12	7.9	-	.01
	6/ 5-12-69	R Waterworks Wells EF 44,89	14	.06	.00	33	7.0	5.3	1.2	68	51	-	-	7.0	.01	0.12	167	112	56	259	11	7.6	-	.02
	5-12-69	R Well EF 90	13	.15	.00	23	5.2	5.2	.6	68	27	3.4	-	2.3	.01	-	109	79	24	181	11	7.6	-	.04
	5-12-69	R Mapleton Well SU 49	15	.07	.00	43	12	14	.7	157	32	-	-	12	.01	-	225	157	28	363	12	7.6	-	.04
	6/ 5-12-69	R Windsor Locks Wells WL 41-44	8.8	.03	.00	28	12	5.1	1.2	89	27	8.4	-	26	.01	-	190	120	46	272	12	7.3	-	.05
Ellington Water Co.	5-14-68	R Well EL 34	18	.05	.02	29	9.2	7.7	1.1	108	15	8.9	-	10	-	-	156	110	22	255	12	7.2	3	.03
Hazardville Water Co.	5-8-69	R Bucken Road Well EF 68	17	.07	.00	32	7.3	7.6	.7	74	29	14	-	16	.01	-	166	110	50	263	12	7.3	-	.05
	5-8-69	R Scitico Well #1 EF 79	15	.16	.00	40	7.1	14	.9	66	35	27	-	44	.01	-	234	129	75	346	11	7.1	-	.08
	5-8-69	R Scitico Well #2 EF 80	16	.11	.00	52	8.2	15	1.2	90	43	26	-	53	.08	-	270	163	139	400	12	7.2	-	.10
	5-8-69	R Maple Street Well EF 81	16	.05	.00	32	1.6	9.3	.6	64	20	13	-	18	.04	-	145	86	34	227	12	7.4	-	.05
	6/ 5-8-69	R Queen Street Wells EF 82,83	13	.05	.13	49	7.2	18	1.4	108	80	6.5	-	.0	.01	-	250	152	63	379	12	8.1	-	.01
	5-8-69	R Town Farm Road Well EF 84	14	.07	.00	35	6.7	6.1	.8	94	27	9.4	-	19	.05	-	158	115	38	262	10	7.5	-	.05
	5-8-69	R Grant Road Well EF 88	17	.06	.00	47	7.0	8.3	1.2	84	62	12	-	1.3	.04	-	227	146	77	332	11	7.9	-	.04
Manchester Water Co.	6/ 4-5-54	F Reservoirs No. 1, 2, and Risley Reservoir	9.0	.08	.01	5.4	1.4	3.4	.7	9	12	5.1	.0	22	-	.00	48	19	12	61	10	6.8	6	-
	5-7-69	Reservoir No. 1	7.9	.16	.11	8.0	1.6	10	1.1	9	14	7.0	-	1.8	.01	-	71	26	19	122	17	6.8	3	.03
	5-7-69	R Well M 76	8.2	.30	.03	8.8	2.6	11	1.0	14	15	22	-	2.6	.03	-	80	32	21	135	14	6.8	-	.03
	5-7-69	R Well M 77	9.1	.18	.00	11	5.4	10	.9	30	17	22	-	4.3	.02	-	104	50	25	169	14	7.0	-	.04
	5-7-69	R Well M 78	14	.03	.00	38	5.8	11	.8	70	38	20	-	2.0	.02	-	190	119	12	296	13	7.6	-	.04
Manchester, City of, Water Department	6/ 4-5-54	R Howard and Porter Reservoirs	9.7	.17	.02	8.6	2.3	7.6	1.1	27	20	4.5	.0	23	-	.00	74	32	10	104	10	6.8	3	-
	5-7-69	R Buckingham Reservoir	6.4	.08	.00	3.2	.7	3.0	.7	3	9.8	3.0	-	.0	.01	-	32	11	8	42	-	5.9	6	.03
	5-7-69	R Globe Hollow Res.	9.9	.11	.01	5.7	1.6	6.2	.6	12	14	5.9	-	1.9	.02	-	49	20	10	78	-	7.0	5	.03
	5-8-70	R Howard Reservoir	6.1	.31	.20	5.4	2.0	10	1.1	8	12	18	-	1.8	.09	-	60	22	15	108	-	6.5	5	.03
	5-7-69	R Porter Reservoir	7.0	.20	.07	4.2	1.5	5.9	1.2	8	12	9.7	-	.0	.01	-	46	16	10	74	-	6.6	8	.03
	5-7-69	R Well M 141	12	.31	.05	20	3.6	7.9	1.1	38	22	17	-	2.8	.02	-	115	65	34	183	-	6.9	-	.03
Metropolitan District Commission	6/ 7-14-51	F Barkhamsted and Nepaug Reservoirs	3.9	.02	.00	3.5	.8	1.5	.4	7	6.8	2.8	.1	.6	-	.00	27	12	6	40	-	6.2	7	-
	6/ 4-3-54	F Barkhamsted and Nepaug Reservoirs	13	.00	.00	3.9	1.2	3.2	.3	10	13	2.2	.0	.4	-	.00	43	17	9	48	10	6.5	3	-
	6/ 4-16-62	F Barkhamsted and Nepaug Reservoirs	5.6	.00	.00	8.0	1.8	2.8	.6	18	11	3.9	1.0	.1	-	-	46	28	13	75	7	7.0	3	-
New Britain, City of, Water Department	7/ 7-11-51	F Shuttle Meadow Reservoir	8.2	.00	.00	9.4	1.4	3.2	.3	16	14	3.2	.4	.2	-	.00	52	29	13	85	22	9.0	2	-
Portland, City of, Water Department	5-9-69	R Portland Reservoir	6.6	.42	.11	4.7	.8	2.8	.8	2	11	4.7	-	.0	.01	-	36	14	13	52	15	5.3	0	.03
	5-9-69	R Well P 69	13	.07	.00	33	3.8	5.6	.9	84	20	8.7	-	11	.14	-	141	98	29	226	10	8.0	-	.04
Rockville Water and Aqueduct Co.	4-29-69	R Shenipsit Lake	3.7	.08	.04	4.1	1.4	5.1	1.0	8	10	9.8	.2	.4	-	-	48	16	10	66	16	6.4	21	.03
Talcottville Water Co.	5-3-68	R Well V 2	14	.00	.18	52	8.5	32	2.5	66	29	101	.0	5.6	-	-	326	165	110	534	13	7.0	2	.06
Vernon Water Co.	4-24-68	R Well V 66	14	.03	.01	30	10	12	1.6	42	31	34	.2	29	-	-	187	116	82	330	12	6.6	1	.07
	4-24-68	R Well V 67	13	.03	.02	55	10	10	.5	42	30	32	.1	31	-	-	236	178	86	410	10	6.8	0	.06
	4-24-68	R Well V 68	12	.04	.00	15	3.0	11	1.2	24	17	25	.2	8	-	-	117	50	30	182	9	6.4	0	.02
	4-24-68	R Well V 69	12	.28	.00	20	8.1	9.8	.7	46	27	70	.2	14	-	-	134	84	46	233	9	6.7	3	.04
	4-24-68	R Well V 70	16	.17	.00	37	22	9.4	.7	136	60	14	.2	12	-	-	240	183	72	397	12	7.7	1	.04

1/ Connecticut Department of Health (Connecticut General Assembly, 1975).
2/ Finished water.
3/ $NO_3 + NO_2$ (as N).
4/ Depending on type of treatment.
5/ Calculated Na plus K, reported as Na.
6/ Composite water sample from all wells indicated.
7/ Shuttle Meadow Reservoir includes water from Wolcott and Whigville Reservoirs and Patton and Whites Bridge Brook.

ABBREVIATIONS

^{o}C	- degrees Celsius (Centigrade)
e.s.t.	- Eastern standard time
ft^2	- square feet
fig.	- figure
ft	- feet
ft^3/d	- cubic feet per day
ft^3/s	- cubic feet per second
$(ft^3/s)/mi^2$	- cubic feet per second per square mile
gal/d	- gallons per day
gal/min	- gallons per minute
(gal/min)/ft	- gallons per minute per foot
in	- inches
$(lb/d)/mi^2$	- pounds per day per square mile
Mgal/d	- million gallons per day
$(Mgal/d)/mi^2$	- million gallons per day per square mile
mg/L	- milligrams per liter
mi	- miles
mi^2	- square miles
mL	- milliliters
mm	- millimeters
msl	- mean sea level (now known as National Geodetic Vertical Datum of 1929)
p.	- page
pl.	- plate
ppm	- parts per million
ug/L	- micrograms per liter
umho	- micromhos

EQUIVALENTS

$^{o}C = (^{o}F - 32) \times 0.555$

1 ft^3/s = 646,317 gal/d = 0.646317 Mgal/d

1 $(ft^3/s)/mi^2$ = 13.57 in of runoff per year

1 in of water upon 1 mi^2 = 17.4 million gallons = 2.32 million ft^3

1 Mgal/d = 694 gal/min = 1.547 ft^3/s

1 $(Mgal/d)/mi^2$ = 21.0 in of runoff per year

1 mg/L = 1 part per million (ppm) for solutions with a density of 1,000 gram per mL

1 mm = 0.001 meter = 0.039 in

Hydraulic conductivity (ft/d) x 7.48 = coefficient of permeability in gallons per day per square foot

Transmissivity (ft^2/d) x 7.48 = coefficient of transmissibility in gallons per day per foot

GLOSSARY

Alkaline-earth metals: Strongly basic metals including calcium, magnesium, strontium, barium, cadmium, and beryllium.

Annual flood: The highest peak discharge in a water year.

Aquifer: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable materials to yield significant quantities of water to wells and springs.

Basalt: A fine-grained, dark-colored igneous rock, commonly called "trap rock".

Bedrock: Solid rock, commonly called "ledge", that forms the earth's crust. It is locally exposed at the land surface in Connecticut but is more commonly buried beneath a few inches to more than 300 feet of unconsolidated materials.

Casing, of wells: Any construction material that keeps unconsolidated earth materials and water from entering a well.

Climatic year: A continuous 12-month period, April 1 through March 31, during which a complete annual streamflow cycle takes place from high flow to low and back to high flow. It is designated by the calendar year in which it begins, and that includes 9 of its 12 months.

Coliform bacteria, total: A particular group of bacteria that are used as indicators of possible sewage pollution. They are characterized as aerobic or facultative anaerobic, gram-negative, nonspore-forming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. In the laboratory, these bacteria are defined as the organisms which produce colonies within 24 hours when incubated at 35°C ± 1.0°C on M-Endo medium (nutrient medium for bacterial growth). Their concentrations are expressed as numbers of colonies per 100 mL of sample.

Continuous-record gaging station: A site on a stream at which continuous measurement of stream stage are made by automatic equipment or made manually at least once a day. These records are converted to daily flow after calibration by flow measurements.

Cone of depression: The depression produced in the water table by the withdrawal of water from an aquifer; in cross section, shaped like an inverted cone with its apex at the pumping well.

Crystalline bedrock: Any metamorphic or igneous bedrock composed of closely interlocking minerals.

Cubic feet per second (ft^3/s): A unit expressing rate of discharge. One cubic foot per second is equal to the discharge of a stream 1 foot wide and 1 foot deep flowing at an average velocity of 1 foot per second.

Direct runoff: Water that moves over the land surface directly to streams or lakes shortly after rainfall or snowmelt.

Discharge: The rate of flow of water from a pipe, an aquifer, a lake, or a drainage basin, in terms of volume per unit of time.

Dissolved solids: The residue from a clear sample of water after evaporation and drying for one hour at 180°C; consist primarily of dissolved mineral constituents, but may also contain organic matter and water of crystallization.

Draft, from a reservoir: A rate of regulated flow at which water is withdrawn from a reservoir.

Drainage basin, drainage area: The whole area or entire land surface that gathers water and contributes it ultimately to a particular stream channel, lake, reservoir, or other body of water.

Drawdown: The lowering of the water level or the reduction in the pressure of the water in a well caused by the withdrawal of water. It is equal to the difference between the static level and the pumping level.

Epilimnion: The top layer of water in a stratified lake, pond, or reservoir; it is between the surface and the thermocline.

Evapotranspiration: Loss of water to the atmosphere by direct evaporation from water surfaces and moist soil combined with transpiration from living plants.

Fault, geologic: A surface or zone of rock fracture along which there has been displacement.

Flood: Any high streamflow overtopping the natural or artificial banks in any reach of a stream.

Flow duration, of a stream: The percentage of time during which specified daily discharges were equaled or exceeded in a given period. The sequence of daily flows is not chronological.

Fracture: A break or opening in bedrock along which water may move.

Frequency: See "recurrence interval".

Gaging station: A site on a stream, lake, or reservoir for systematic observations of gage height or discharge.

Ground water: Water in the saturated zone.

Ground-water discharge: The discharge of water from the saturated zone by 1) natural processes such as ground-water runoff and ground-water evapotranspiration and 2) artificial discharge through wells and other manmade structures.

Ground-water divide: A line on a water table on each side of which the water table slopes downward in a direction away from the line. In the vertical dimension, a plane across which there is no ground-water flow.

Ground-water evapotranspiration: Ground water discharged into the atmosphere in the gaseous state either by direct evaporation or by the transpiration of plants.

Ground-water outflow: The sum of ground-water runoff and underflow; all natural ground-water discharge from a drainage area exclusive of ground-water evapotranspiration.

Ground-water recharge: The addition of water to the saturated zone by 1) natural processes, such as infiltration of precipitation and 2) artificial recharge through basins, sumps, and other manmade structures.

Ground-water runoff: Ground water that has discharged into stream channels by seepage from saturated earth materials.

Hardness, of water: The physical-chemical characteristic of water that is commonly recognized by the increase of quantity of soap required to produce lather. It is attributable to the presence of alkaline earths (principally calcium and magnesium) and is expressed as equivalent calcium carbonate ($CaCO_3$).

Head, static: The height of the surface of a water column above a standard datum that can be supported by the static pressure at a given point.

Hydraulic boundary: A physical feature that limits the areal extent of an aquifer. The two types of boundaries are termed impermeable-barrier boundaries and line-source boundaries.

Hydraulic conductivity: A measure of the ability of a porous medium to transmit a fluid. The material has a hydraulic conductivity of unit length per unit time if it will transmit in unit time a unit volume of water at the prevailing kinematic viscosity through a cross section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head over unit length of flow path.

Hydraulic gradient: The change in static head per unit of distance in a given direction. If not specified, the direction is generally understood to be that of the maximum rate of decrease in head.

Hydrograph: A graph showing stage (height), flow, velocity, or other property of water with respect to time.

Hypolimnion: The bottom layer of water in a stratified lake, pond, or reservoir; it is beneath the thermocline.

Igneous: Descriptive term for rocks formed by solidification of molten or partly molten magma, such as basalt or granite.

Inches of water: Water volume expressed as the depth, in inches, to which it would accumulate if spread evenly over a particular area.

Induced infiltration: The process by which water infiltrates an aquifer from an adjacent surface-water body in response to pumping.

Induced recharge: The amount of water entering an aquifer from an adjacent surface-water body by the process of induced infiltration.

Kinematic viscosity: The ratio of the viscosity of a fluid to its density.

Mean (arithmetic): The sum of the individual values of a set, divided by the number of values in the set; popularly called the "average".

Median: The central value when values in a set are arranged according to rank; it is an average of position, whereas the <u>mean</u> is an average of quantity.

Metamorphic: Descriptive term for rocks such as gneiss and schist which have formed in the solid state from other rocks.

Methylene blue active substance (MBAS): A measure of apparent detergents, as indicated by the formation of a blue color when methylene blue dye reacts with synthetic detergent compounds.

Micrograms per liter (ug/L): A unit for expressing the concentration of chemical constituents in solution by weight per unit volume of water. One thousand micrograms is equivalent to 1 milligram.

Milligrams per liter (mg/L): A unit for expressing the concentration of chemical constituents in solution by weight per unit volume of water.

Noncarbonate hardness: A measure of the amount of alkaline earth cations in excess of available carbonate (and bicarbonate) anions.

Nutrients: Compounds of nitrogen, phosphorous, and other elements essential for plant growth.

Partly-penetrating well: A well that is not open to the entire saturated thickness of the aquifer.

Partial-record gaging station: A site at which measurements of stream elevation or flow are made at irregular intervals exceeding a day.

Perennial stream: A stream that flows during all seasons of the year.

pH: The negative logarithm of the hydrogen-ion concentration. A pH of 7.0 incidates neutrality; values below 7.0 denote acidity, those above 7.0 denote alkalinity.

Phytoplankton: Plant microorganisms, such as certain algae, living unattached (floating) in the water.

Precipitation: The discharge of water from the atmosphere, in either a liquid or solid state.

Recurrence interval: The average interval of time between extremes of streamflow such as floods or droughts, that will at least equal in severity a particular extreme value over a period of many years. Frequency, a related term, refers to the average number of such extremes during the same period, the date of a drought or flood of a given magnitude cannot be predicted, but the probable number of such events during a reasonably long period of time may be estimated within reasonable limits of accuracy.

Reference period: A period of time chosen so that comparable data may be collected or computed for that period. Streamflow data in this report are based on climatic years 1930 to 1959 or water years 1931 to 1960.

Runoff, total: That part of the precipitation that appears in streams; it includes ground-water and surface-water components. It is the same as streamflow unaffected by artificial diversions, storage, or other works of man in or on the stream channels.

Saturated thickness: Thickness of an aquifer below the water table.

Saturated zone: The subsurface zone in which all open spaces are filled with water under pressure greater than atmospheric.

Sediment: Fragmental material that originates from weathering of rocks and is commonly transported by, suspended in, or deposited by water.

Sedimentary: Descriptive term for rocks deposited as sediments and later compacted or cemented to form consolidated rock.

Specific capacity, of a well: The rate of discharge of water divided by the corresponding drawdown of the water level in the well [(gal/min)/ft].

Specific conductance, of water: A measure of the ability of water to conduct an electric current, expressed in micromhos per centimeter at 25°C. It is related to the dissolved-solids content and serves as an approximate measure thereof.

Specific yield: The ratio of the volume of water that a rock or soil, after being saturated, will yield by gravity, to its own volume.

Storage coefficient: The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, the storage coefficient is virtually equal to the specific yield.

Stratified drift: A predominantly sorted sediment laid down by or in meltwater from a glacier; includes gravel, sand, silt, and clay, deposited in layers.

Streamflow: The discharge that occurs in a natural channel without regard to the effect of diversion or regulation.

Thermal stratification: The forming of layers of water with different temperatures in most open-water bodies.

Thermocline, metalimnion: The middle zone in a stratified lake, pond, or reservoir, between the epilimnion and the hypolimnion, in which the change in temperature with depth exceeds 1°C per meter.

Till: A predominantly nonsorted, nonstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay, mixed in various proportions.

Transmissivity: The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient. Equal to the average hydraulic conductivity times the saturated thickness. In some previous reports of this series, transmissivity is expressed as the coefficient of transmissibility.

Transpiration: The process whereby plants release water vapor to the atmosphere.

Turbidity, of water: The extent to which penetration of light is restricted by suspended sediment, microorganisms, or other insoluble material. Residual or "permanent" turbidity is that caused by insoluble material that remains in suspension after a long settling period.

Unconfined aquifer (water-table aquifer): One in which the upper surface of the saturated zone, the water table, is at atmospheric pressure and is free to rise and fall.

Unconsolidated: Loose, not firmly cemented or interlocked; for example, sand in contrast to sandstone.

Underflow: The downstream flow of water through the permeable deposits that underlie a stream.

Uniformity coefficient: A quantitative expression of sorting of an earth material. It is the quotient of 1) the diameter of a grain that is just too large to pass through a sieve that allows 60 percent of the material, by weight, to pass through, divided by 2) the diameter of a grain that is barely too large to pass through a sieve that allows 10 percent of the material, by weight, to pass through. Poorly sorted deposits, such as dirty gravel, have high uniformity coefficients; well-sorted deposits such as uniform sand have low uniformity coefficients.

Unsaturated zone: The subsurface zone above the water table.

Volcanic: Descriptive term for rocks formed by the cooling of lava.

Water table: The surface in an unconfined water body at which the pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water just far enough to hold standing water. In wells penetrating to greater depths, the water level will stand above or below the water table if an upward or downward component of ground-water flow exists.

Water year: A continuous 12-month period, October 1 through September 30, during which a complete streamflow cycle takes place from low to high flow and back to low flow. It is designated by the calendar year in which it ends, and that includes 9 of its 12 months.

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