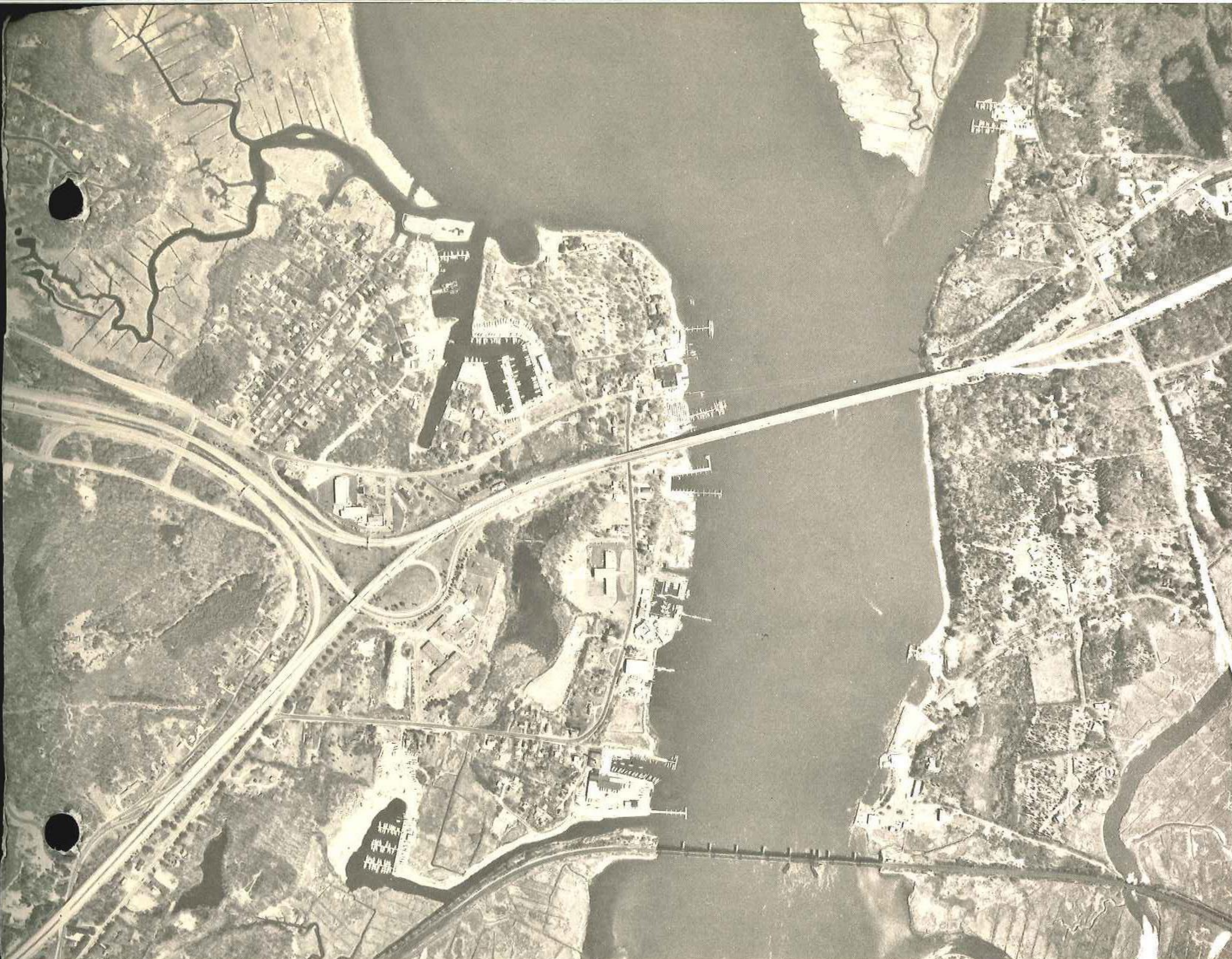


WATER RESOURCES INVENTORY OF CONNECTICUT
PART 10
LOWER CONNECTICUT RIVER BASIN

BY

LAWRENCE A. WEISS, JAMES W. BINGHAM, MENDALL P. THOMAS

U.S. GEOLOGICAL SURVEY

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

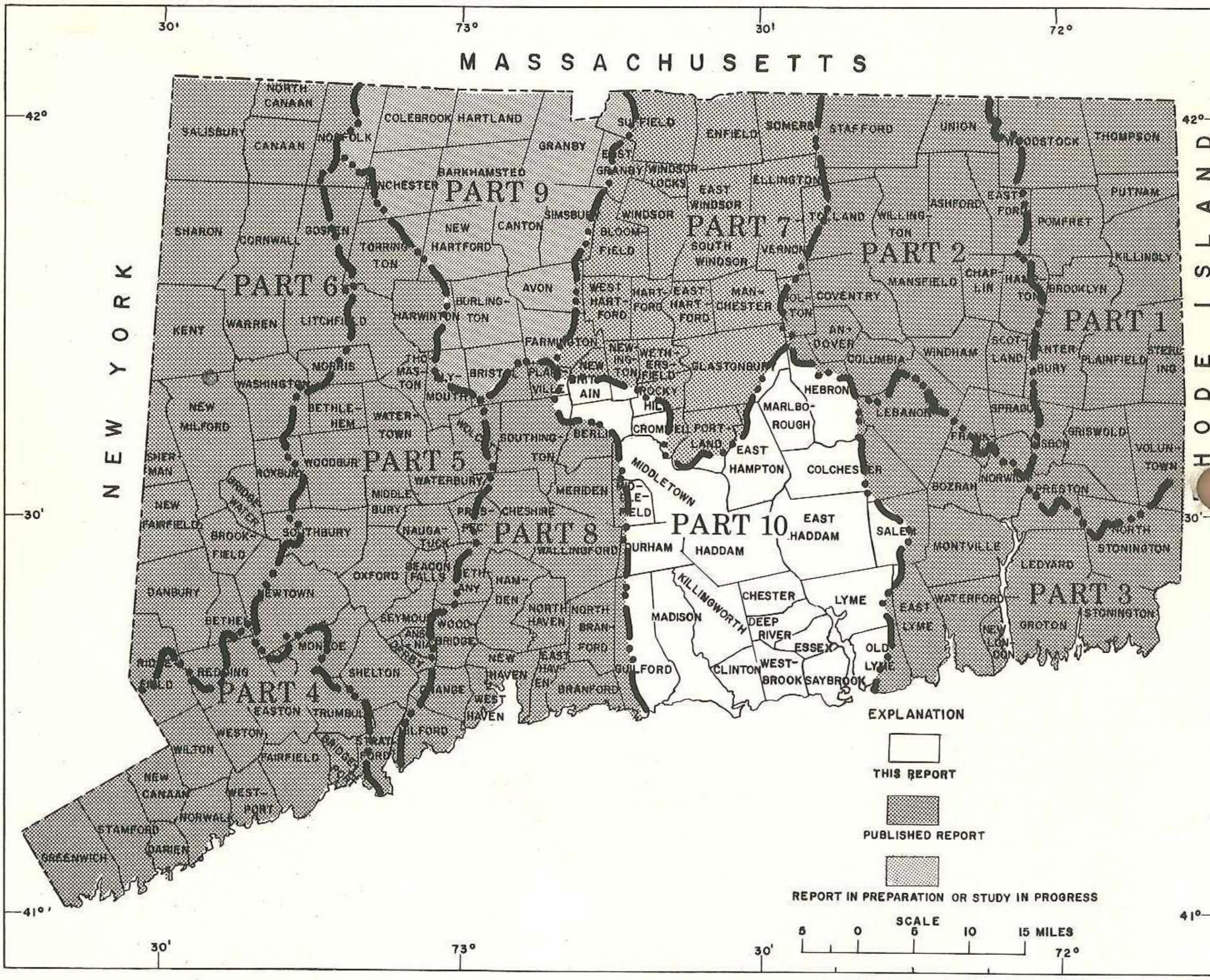
CONNECTICUT WATER RESOURCES BULLETIN NO. 31

1982

COVER PHOTO.--The Connecticut River, the largest river in New England, at Old Saybrook and Old Lyme, Connecticut. At this point the Connecticut River drains an area of approximately 11,263 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

PART 10-Lower Connecticut River Basin

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SUMMARY

The lower Connecticut River basin study area in south-central Connecticut includes 639 square miles and is drained principally by the Connecticut River and by seven smaller streams that flow directly to Long Island Sound between the West River on the west and the Connecticut River on the east. The population in 1979 was estimated to be 210,380. Much of the industrial development and population centers are in the Mattabesset River basin in the northwestern part, and the largest water use is also in the Mattabesset River basin.

Precipitation averages 47 inches per year and provides an abundant supply of water. About 20 inches returns to the atmosphere as evapotranspiration, and the remainder either flows directly to streams or percolates to the water table, eventually discharging to Long Island Sound. Small quantities of water are exported from the basin by the New Haven and Meriden Water Departments, and small quantities are imported by the New Britain Water Department and Metropolitan District Commission. Precipitation during 1931-60 resulted in an average annual runoff of 302 billion gallons. If inflow from the Connecticut River is added to the average annual runoff, then 4,370 billion gallons per year is potentially available for water use.

The domestic, institutional, commercial, and industrial (other than cooling water) water use for 1970 was 7 billion gallons, which is only 3 percent of the total water used, whereas 97 percent of the total is cooling water for power plants. Approximately 60 percent of the 7 billion gallons is treated before being discharged back to the streams.

The total amount of fresh water used during 1970 was estimated to be 256,000 million gallons (Mgal), of which 247,000 Mgal was used for cooling water at steam electric-generating plants. The quantity for domestic, commercial, industrial, and agricultural uses was 9,000 Mgal, which was approximately 120 gallons a day per person. Public water systems providing 70 percent of these requirements and all the systems supplying water met the drinking water standards of the Connecticut General Assembly (1975).

Stratified drift is the chief aquifer capable of large sustained yields of water to individual wells. Yields of 53 inventoried screened wells tapping stratified drift range from 2 to 1,570 gallons per minute (gal/min); median yield is 397 gal/min.

Till is widespread and generally provides only small amounts of water. Wells in till normally yield only a few hundred gallons of water daily and may be inadequate during dry periods. The thickness of till ranges from 0 to 150 feet; a median thickness of 26 feet is estimated from information provided in drillers' logs of 467 wells penetrating underlying bedrock. The till is generally used only as an emergency or secondary source of water.

Bedrock aquifers underlie the entire area and include sedimentary and crystalline (igneous and metamorphic) rock types. These aquifers supply small and usually reliable quantities of water to wells and are the chief source of water for many rural homes and farms. About 90 percent of the wells tapping bedrock yield at least 2 gal/min. The median yields from wells tapping aquifers in sedimentary, igneous, and metamorphic rocks are 11, 8, and 6.5 gal/min, respectively.

The quantity of water potentially available from stratified drift was estimated on the basis of hydraulic characteristics of the aquifers, mathematical modeling of the aquifer system, and evaluation of natural and induced recharge. Long-term yields estimated for ten areas underlain by significant thicknesses of stratified drift range from 0.4 to 4.4 million gallons per day (Mgal/d). A change in well spacing or number could increase the long-term yields, but detailed modeling verification studies are needed to confirm optimal well locations.

The chemical and physical (turbidity, color, taste, and sediment load) quality of water is good. The water is generally low in dissolved solids and is classified as soft to hard. Surface water is less mineralized than ground water, especially during high flow, when it is primarily derived from surface runoff rather than ground-water runoff. A median dissolved-solids concentration of 42 milligrams per liter (mg/L) and median hardnesses of 18 mg/L were determined from water samples collected from 26 streams during the high-flow period. During the low-flow period, median dissolved-solids concentration of 61 mg/L and median hardnesses of 27 mg/L were determined from samples from the same streams.

The quality of water in stratified-drift and crystalline-rock aquifers is generally better than that in the sedimentary-rock aquifers. Water from 32 wells tapping stratified drift and 37 tapping crystalline rock had median dissolved-solids concentrations of 116 mg/L; and 33 wells tapping stratified drift and 42 tapping crystalline rock had median hardnesses of 73 mg/L and 68 mg/L, respectively. Water from 32 wells tapping sedimentary rock had median dissolved-solids and hardness concentrations of 231 and 156 mg/L, respectively. Sedimentary rock generally yields the hardest water.

Iron and manganese occur in objectionable concentrations in places, particularly in water from streams draining swamps and in water from aquifers either rich in iron and manganese-bearing minerals or where the reducing environment for solution of these minerals is favorable. Concentrations of

iron in excess of 0.3 mg/L and manganese in excess of 0.05 mg/L were found in 35 percent of the high streamflow samples, in 65 percent of the low streamflow samples, and in 45 percent of the ground-water samples. Most of the high iron and manganese concentrations in streams and aquifers are found east of the Connecticut River.

Human activities and tidal influence along the coast have modified the quality of water in much of the study area. The greatest influence from human activities has been in the northwestern part, in the Mattabesset River basin. There, the quality of water has been affected by domestic and animal wastes, which cause high dissolved-solids concentrations, high nitrate and phosphate loads, and high bacterial counts. In the entire area, high nitrate in ground water occurs only locally, and its presence in an individual water supply is chiefly a function of its proximity to sources of contamination, of well construction, and of thickness of overburden. Thirty public-supply wells did have water that had high sodium concentrations or objectionable iron and manganese concentrations, but these are not considered health hazards in the concentrations found in the water samples. Streams, wetlands, and some aquifers along the south boundary of the basin contain salty water because of tidal movement or extensive ground-water withdrawals. High sediment concentrations also occur as a result of tidal influence in this area.

INTRODUCTION

PURPOSE AND SCOPE

Connecticut has experienced a significant increase in population in the past few decades, accompanied by industrial growth, increased energy needs, changes in patterns of land use. These factors have contributed to an increased demand for water that is expected to continue. The inflow and quality of the water resources of the study area generally are sufficient for immediate and anticipated water needs, but increasing stress on these resources from a growing population may cause shortages or a deterioration in quality. Therefore, as stress on the resource increases, so does the need for accurate information for planning additional development and to maintain quality.

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 (1967), the U.S. Geological Survey, in cooperation with the Connecticut Department of Environmental Protection (previously the Water Resources Commission), has undertaken a series of studies to determine the quantity and quality of water available in the State. For these investigations, Connecticut was divided into ten study areas, each bounded by natural drainage divides, State boundaries, and the ocean. (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 the seventh of the 10 study areas. A companion report (Bingham and others, 1975), lists much of the hydrologic data on which this report is based. A list of cooperative reports on the water resources of other areas in Connecticut is given on the back cover of this report.

LOCATION AND EXTENT OF STUDY AREA

The lower Connecticut River basin study area, as defined in this report, includes 639 square miles in south-central Connecticut. The area is drained principally by the Connecticut River between a point just upstream from the Mattabesset River and the mouth of the Connecticut River at Long Island Sound. It includes several smaller basins totalling 131 square miles; these drain into Long Island Sound between the mouth of the Connecticut River and the west boundary of the West River drainage divide (fig.1).

The Connecticut River basin in Connecticut has been divided into three study areas. The lower Connecticut River basin describes the farthest downstream area. A second report (Ryder and others, 1981) covers the upper Connecticut River basin, which is adjacent to the north and extends from the Massachusetts State line to a point just upstream from the Mattabesset River (fig. 1) but excludes the Farmington River basin. A third report covers the Farmington River basin which is not yet published (index map front cover).

Only part of New Britain and all of Middletown in the northwestern part is urbanized. Although these two highly industrialized cities have a third of the area's population, they cover only 8 percent of its drainage area. The economy of the coast is based principally on summer recreation. Near the coast, the Connecticut River and smaller streams are affected by tide and saltwater intrusion.

Transportation is well developed. Interstate Highways 91 and 95 serve the northern and southern parts, and State routes 9 and 2 serve the central and eastern parts, respectively. Amtrak and Conrail rail systems serve New Britain and the coast, and spur lines serve several smaller towns.

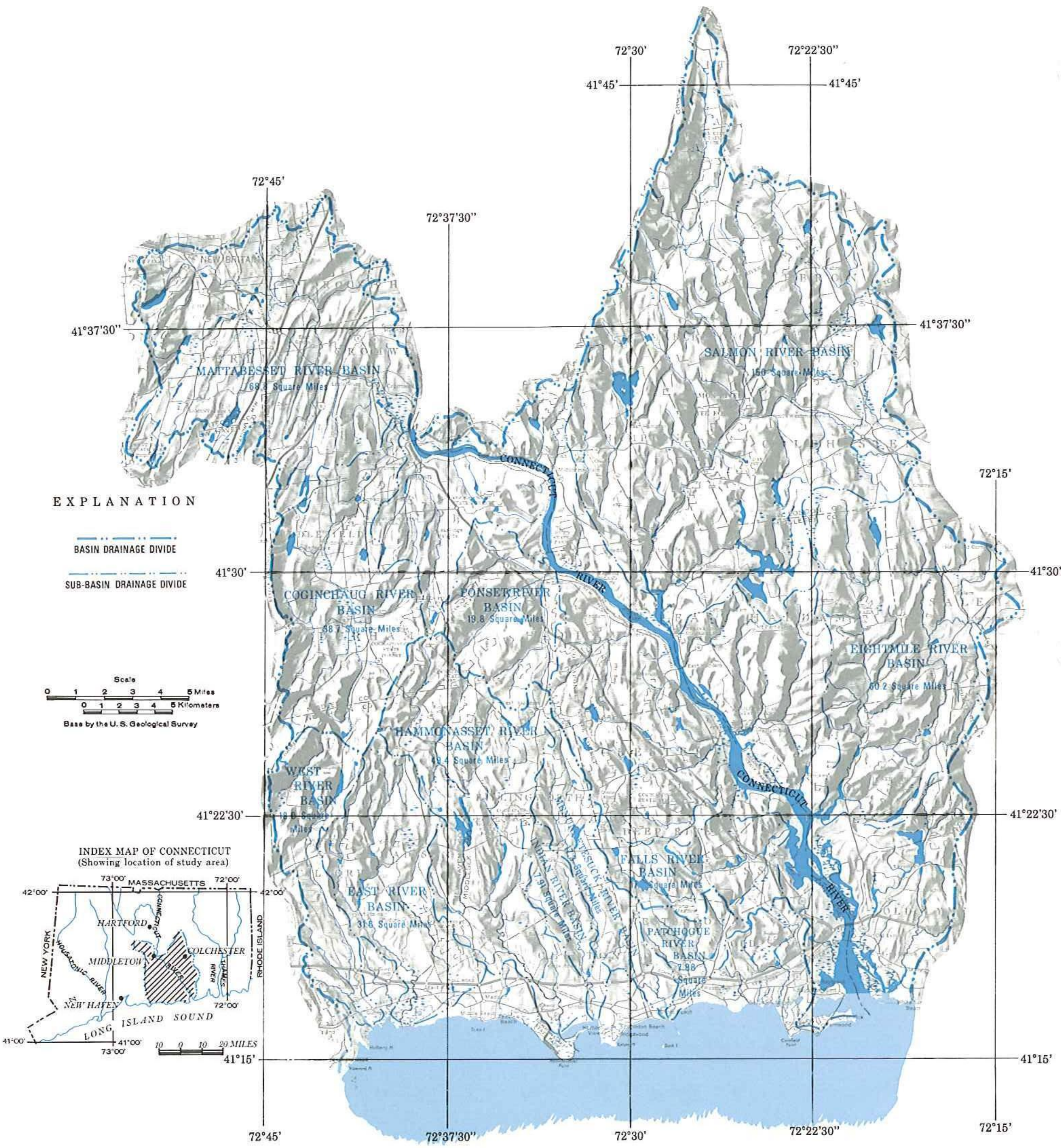


Figure 1.--The lower Connecticut River basin study area

ACKNOWLEDGMENTS

The data on which this report is based were collected and analyzed by personnel of the U.S. Geological Survey. Unpublished information was obtained from the files of the U.S. Corps of Engineers and from several State agencies, including the Department of Environmental Protection, Water and Related Resources Unit (formerly Water Resources Commission), the Fish and Water Life Unit (formerly Board of Fisheries and Game), the Geological and Natural History Survey of the Natural Resources Center (formerly Connecticut Geological and Natural History Survey), and the Department of Transportation. Ground-water data obtained from Geraghty and Miller, Inc., consulting ground-water geologists, and well and test-hole data provided by the S. B. Church Co. contributed significantly to the study. Other information and assistance was provided by personnel of the Colchester Water Department, Middletown Water Department, Connecticut Water Company, and the towns of Berlin and Old Lyme, as well as property owners, well-drilling contractors, consultants, planning agencies, and other company and public officials. All have helped to make this report possible, and their contributions are appreciated.

The authors wish to gratefully acknowledge the interest and support extended by Stanley J. Pac, Commissioner, State Department of Environmental Protection and Hugo F. Thomas, Director, Natural Resources Center of the State Department of Environmental Protection.

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 commonly 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, percolates to the water table (top of the saturated zone in permeable soil and rock materials) and flows to points of discharge at springs or into streams and lakes. The part that reaches the streams, lakes, and eventually the oceans, is evaporated back into the atmosphere to complete the cycle.

As water moves through the hydrologic cycle, large amounts are stored temporarily (1) in the atmosphere as vapor or clouds (2) on the land surface in streams, lakes, and oceans and (3) beneath the land surface as ground water. The amount of such storage changes constantly as the water moves, and the physical, chemical, and biological properties of the water also change, as described below.

THE WATER BUDGET

The hydrologic system in a drainage basin can be expressed by a water budget, which, like a fiscal budget, lists deposits, withdrawals, and amounts on hand. The deposits, or additions of water consist of precipitation on the area, inflow from the upper Connecticut River basin upstream from the mouth of the Mattabesset River, and inflow of ground water from beyond the area boundary. Withdrawals consist of surface runoff, ground-water underflow, evapotranspiration, and diversions The amount on hand--stored within the basin-is constantly changing. The amount in each element of the budget may vary seasonally and from year to year, but the budget always balances. Taking into account changes in storage, the withdrawals are equal to the deposits. The approximate average yearly amounts involved in each of the major elements of the water budget are listed in figure 2.

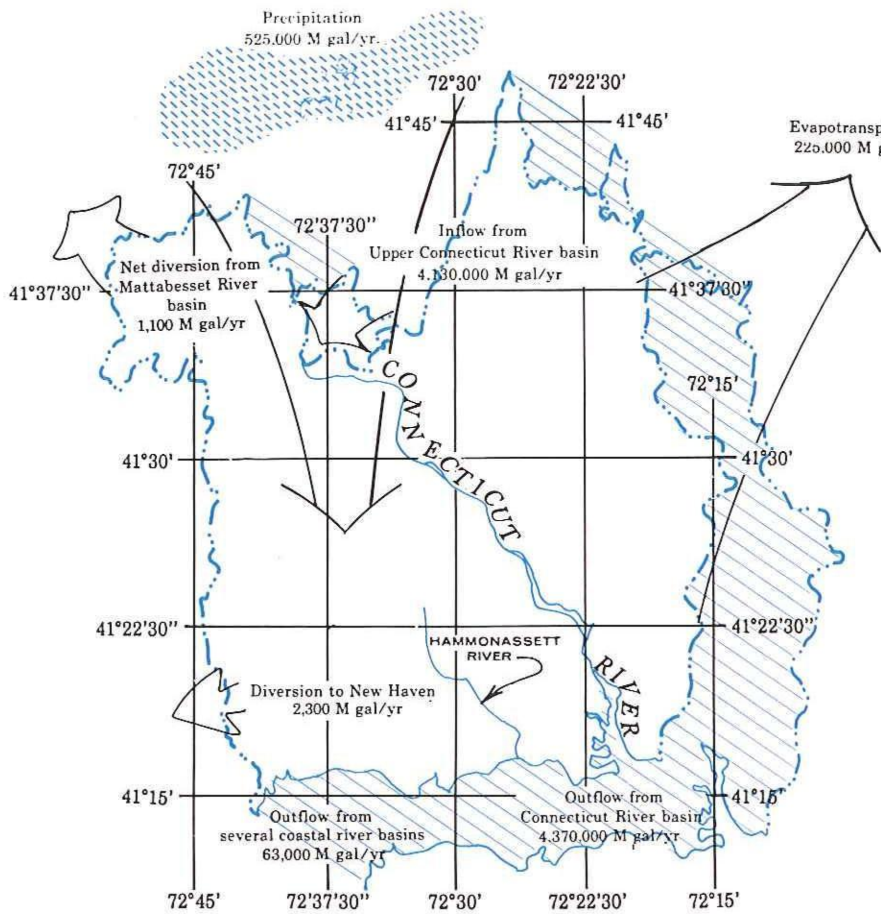


Figure 2.--The average annual water budget in millions of gallons per year (Mgal/yr)

SOURCES OF WATER

PRECIPITATION

The mean monthly and mean annual precipitation during October 1930 to September 1960, as computed from records at the New Haven, New London, and Hartford weather stations, are given in table 1. The data were weighted in proportion to the area represented by each station.

Mean monthly precipitation is fairly uniform throughout the year, as shown in figure 3, and ranges from 3.24 inches in February to 4.52 inches in November; the average is 3.95 inches per month. During the 1931-60 water years, minimum monthly precipitation ranged from 0.59 inch in August 1935 to 1.88 inches in March 1946, and maximum monthly precipitation ranged from 5.12 inches in February 1960 to 14.55 inches in September 1938.

The mean annual precipitation of 47.34 inches on the 639 square miles is equivalent to 525,000 Mgal (fig. 2).

Table 1.--Mean monthly and mean annual water budget calculated for the lower Connecticut River basin for the 1931-60 water years

Month	Precip-itation	Evapo-transpir-ation	Precipi-tation minus evapo-transpir-ation	Runoff	Change in storage 2/
	inches	of	water		
Oct	3.52	1.54	1.98	1.11	.87
Nov	4.52	.74	3.78	2.03	1.75
Dec	4.06	1/ .20	3.86	2.81	1.05
Jan	4.06	1/ .20	3.86	3.12	.74
Feb	3.24	1/ .20	3.04	2.84	.20
Mar	4.49	.45	4.04	4.90	- .86
Apr	4.00	1.31	2.69	4.02	-1.33
May	3.79	2.47	1.32	2.63	-1.31
June	3.53	3.34	.19	1.36	-1.17
July	3.89	3.89	.00	.68	- .68
Aug	4.21	3.46	.75	.67	.08
Sept	4.03	2.45	1.58	.92	.66
Mean annual	47.34	20.25	27.09	27.09	0

1/ Estimated for times when air temperature was above freezing. It is assumed to be zero when air temperature is at or below freezing.

2/ Minus sign indicates net loss in storage, no sign indicates net gain.

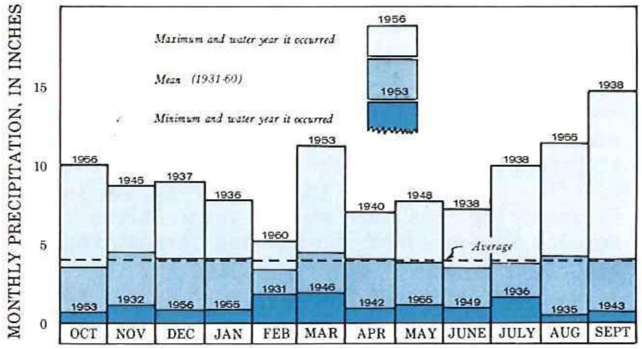


Figure 3.--Monthly precipitation on the Connecticut River basin

STREAMFLOW AND GROUND-WATER UNDERFLOW

Although precipitation on the area is a major source of replenishment, a considerably larger source is the streamflow entering from the upper Connecticut River basin upstream from the mouth of the Mattabesset River. There, the average annual inflow is 4,130,000 Mgal/yr. Ground-water inflow is probably negligible here, because of the fine-grained sediments and low hydraulic gradient. Inflow and outflow of water are listed in figure 2.

LOSSES OF WATER

RUNOFF

Long-term records of runoff are available from four widely distributed stations. The areas represented by these runoff records total 156 square miles, or about 25 percent of the total. This 156 square miles is probably representative of overall runoff, for which mean monthly and mean annual totals are given in table 1. As shown in table 1 and figure 4, the mean monthly runoff follows a marked seasonal cycle, being much lower in August (0.67 inch) than in March (4.90 inches). This seasonal cycle 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. Minimum monthly runoff ranged from 0.03 inch in September 1943 to 2.40 inches in March 1941, and maximum monthly runoff also varied widely, ranging from 3.14 inches in August 1955 to 9.60 inches in March 1953 (See section on floods.)

Based on a mean annual runoff of 27.09 inches from the entire 639 mi^2, the mean annual runoff from the 508 mi^2 basin drained directly by the

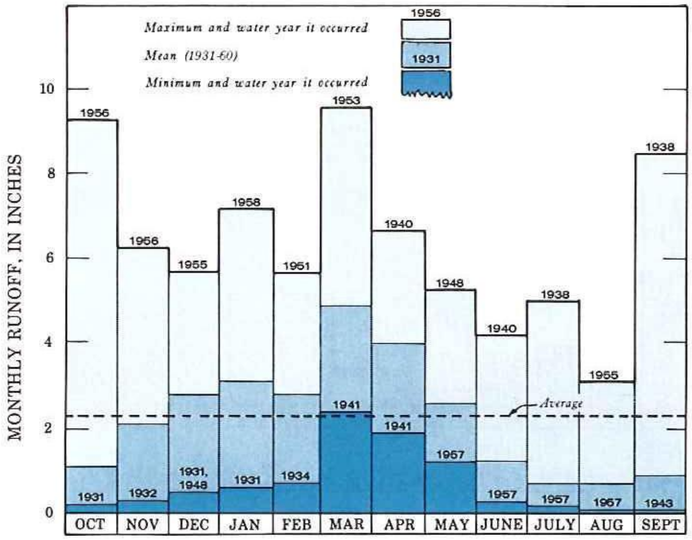


Figure 4.--Mean monthly runoff from the Connecticut River basin

Connecticut River totals 240,000 Mgal/yr and that from the remaining 131 mi^2 totals 62,000 Mgal/yr. A small but undetermined amount of ground water discharges directly into Long Island Sound.

EVAPOTRANSPIRATION

Much of the precipitation is returned to the atmosphere by evaporation and transpiration. The combined process of evapotranspiration (E.T.) is difficult to measure directly and is commonly computed as the remainder after all other gains and losses have been calculated. Measurements of reservoir levels and ground-water levels indicate that surface-water and ground-water storage do not change substantially over long periods. Therefore, mean annual E.T. is estimated to be equal to the mean annual precipitation of 47.34 inches minus the mean annual runoff of 27.09 inches, or 20.25 inches.

The E.T. rate changes throughout the year because of changes in air temperature and duration of daylight (Thornthwaite, 1952, p. 382). For example, it is 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 E.T. is relatively constant for a given locality. Theoretical mean monthly E.T. is computed by a method similar to that described by Thornthwaite and Mather (1957) and is given in table 1 and shown in figure 5. The mean annual E.T. is 20.25 inches, or 225,000 Mgal/yr.

47
2

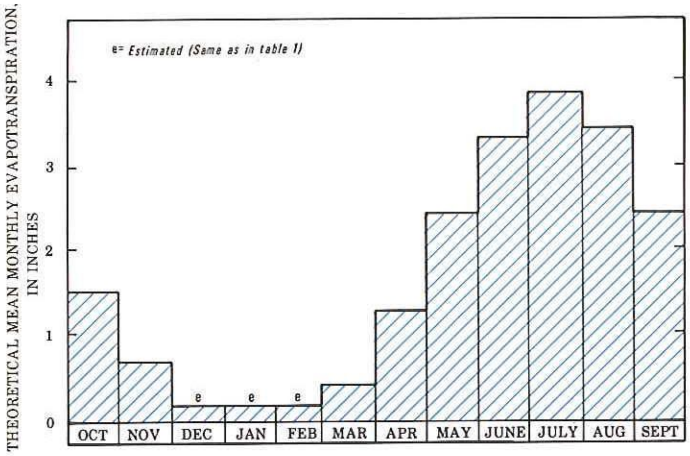


Figure 5.--Mean monthly evapotranspiration

DIVERSIONS

The amount of water diverted by cities is small. Meriden diverts 1,100 Mgal/yr from the Mattabesset River, and New Haven diverts 2,300 Mgal/yr from the Hammonasset River. New Britain diverts 2,200 Mgal/yr from the Quinnipiac and Farmington Rivers for water supply within the area, but diverts an equivalent amount out of the basin to its Mattabesset District sewage plant in Cromwell in the upper Connecticut River basin. The Metropolitan District Commission diverts 600 Mgal/yr into the basin for water supply for the town of Newington, but this flows back to the sewage-treatment plant in Hartford with no net change.

SUMMARY

The mean monthly water budget is shown in figure 6, from values given in table 1. Precipitation in late autumn and winter exceeds evapotranspiration, which results in increased storage (in lakes and aquifers) 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 may, thereby, change in lakes, aquifers, and the soil zone and beneath stream channels.

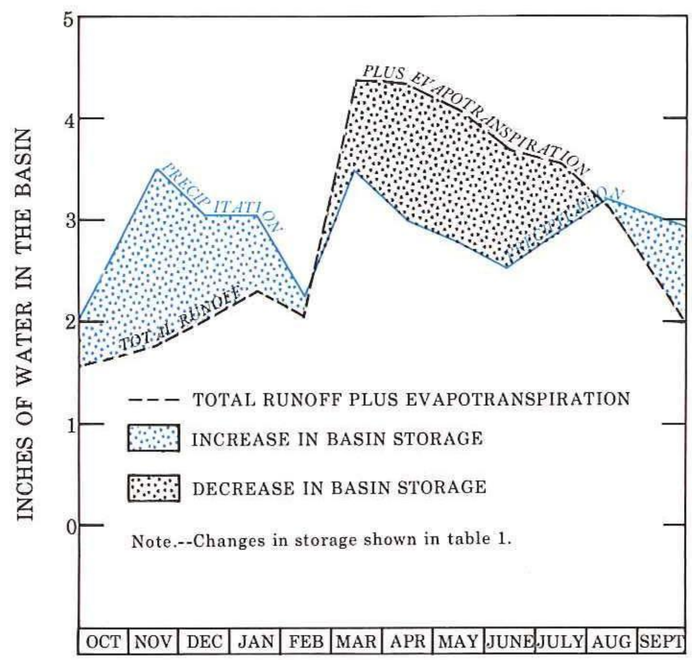


Figure 6.--Mean monthly water budget

WATER QUALITY CHANGES WITHIN THE HYDROLOGIC CYCLE

Water moving through the hydrologic cycle undergoes changes in chemical and physical properties. Water as precipitation dissolves particles from the atmosphere and, upon reaching the land, is further modified by reactions with soils, rocks, and organic matter. The chemistry of water, therefore, depends largely on the composition and physical properties of the materials it contacts and on the length of time of contact. Thus, ground water, which moves slowly through its environment, is generally more mineralized than surface water. Lakes and streams are a mixture of surface runoff and ground-water runoff and are intermediate in mineral content. The types of water-quality changes resulting from the diverse environments of the hydrologic cycle are shown diagrammatically in figure 7.

Soot and motor exhaust may affect the composition of precipitation; animal wastes, fertilizers, petroleum residues, and road salts, may degrade the quality of surface runoff; leachate from landfills and septic tanks may contaminate ground water; and industrial wastes may contaminate streams and ground water. Figure 8 shows man-imposed changes in the quality of water as it passes through the hydrologic cycle.

QUALITY OF PRECIPITATION

Rainfall composition varies from place to place, from one storm to another, and within a single storm. The path of an air mass has a major influence on the composition of precipitation. Rain from oceanic storms commonly contains significant concentrations of chloride and sodium ions. Moisture in storms that pass over industrial areas contains impurities from fumes and smoke, particularly sulfate and nitrate ions. High sulfate concentration is usually associated with acidic rain near urban areas. Dust, salt spray, industrial wastes, unburned fuel, pesticides, and agricultural chemicals are dissolved and removed from the atmosphere by precipitation. Rain at the beginning of a storm may ini tially contain higher concentrations of dissolved solids than later rain.

To evaluate the quality of rainfall in the State, 133 composite monthly samples of precipitation from 18 locations were collected and analyzed between 1963 and 1969. These samples had dissolved-solids concentrations ranging from 2 to 236 mg/L, with a median of 20 mg/L. The median concentration is equivalent to 4.5 pounds of

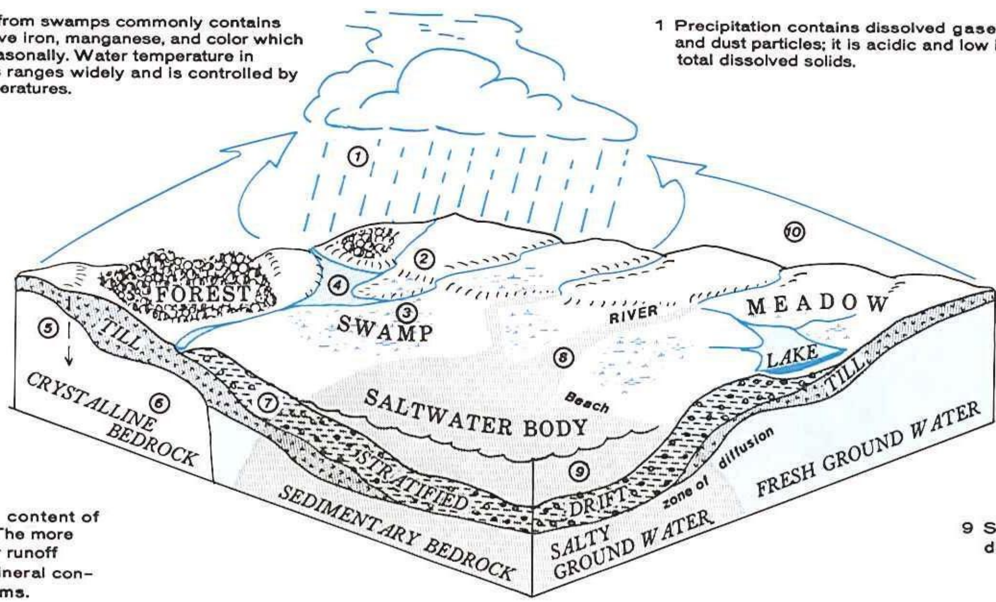
2 Surface runoff erodes soils and organic materials which increases turbidity and sediment concentrations. Water temperatures follow seasonal air temperatures but are less extreme.

3 Runoff from swamps commonly contains excessive iron, manganese, and color which vary seasonally. Water temperature in swamps ranges widely and is controlled by air temperatures.

1 Precipitation contains dissolved gases and dust particles; it is acidic and low in total dissolved solids.

4 Water stored in lakes, ponds, and reservoirs has reduced turbidity, sediment load, and color. Thermal stratification in deep water depletes oxygen in the lower layers.

10 Evapotranspiration moves in vapor form from land surface to the atmosphere. Atmospheric water is the lowest in dissolved-solids content of any water in the cycle.



5 Infiltration increases the mineral content of water during low-flow periods. The more highly mineralized ground-water runoff may substantially increase the mineral content in water of smaller streams.

9 Salt water in ocean or sound has highest dissolved solids concentration.

6 Water in bedrock is influenced by the composition of the bedrock and surficial materials through which the water moves.

8 Estuarine water is mixture of salty and fresh water

7 Water in stratified drift is influenced by the composition of surficial materials. Dissolved carbonate minerals increase hardness. The quality of water moving upward from bedrock also influences the quality of water in surficial deposits.

Source: Mazzaferro and others, 1979

Figure 7.—The natural quality of water in the hydrologic cycle

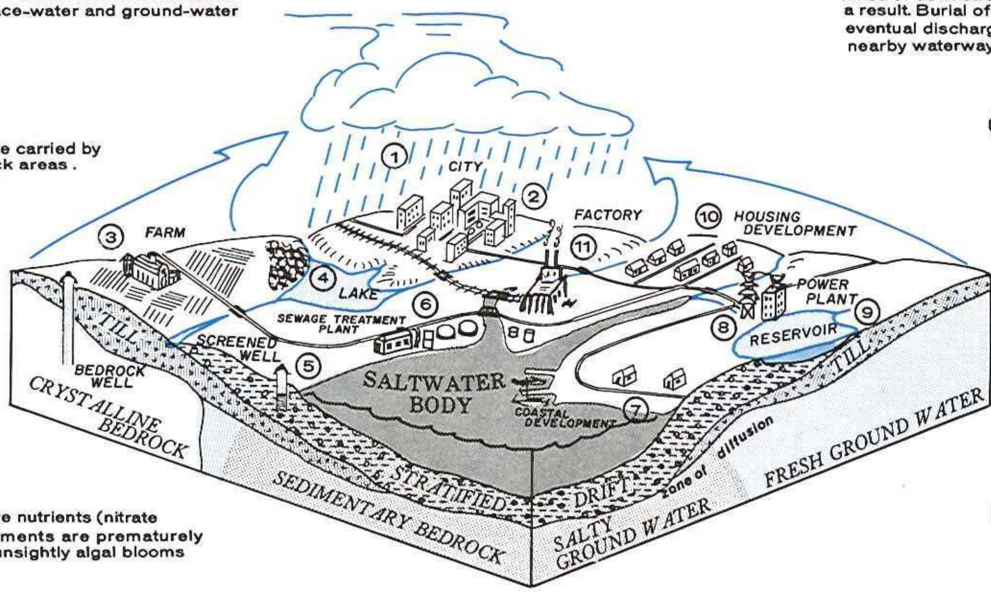
(1) Gaseous, liquid, and solid materials produced by man's activities are dissolved and absorbed by precipitation and returned to earth. Sulfur lead, unburned hydrocarbons, dust, soot, and fly ash all contribute to mineralization of precipitation before it reaches land surface.

(2) Petroleum residue from paved areas, leachate from wastes and fertilizers from lawns and gardens are all carried by runoff from populated areas. Construction in developing areas increases turbidity. Salt used in winter road maintenance enters both surface-water and ground-water bodies.

(11) Industry contributes waste to the air, water, and ground. Many industrial wastes are difficult and expensive to treat. Often direct discharge to streams is the disposal method employed and miles of downstream reach are contaminated as a result. Burial of solid waste merely delays the eventual discharge of the noxious material into nearby waterways or the ground-water reservoir.

(3) Animal wastes and fertilizers are carried by runoff from agricultural and stock areas.

(10) Housing developments remote from urban areas lack central water supply and sewage treatment facilities. Improper design and placement of individual wells and septic tanks may lead to large-scale aquifer contamination and serious health problems.



(4) Lakes and ponds which receive nutrients (nitrate and phosphate ions) and sediments are prematurely aged. Continuation results in unsightly algal blooms in summer.

(9) Reservoirs and other impoundments improve water quality by trapping sediments. Turbidity and color of the water improve with storage. Excessive sedimentation will gradually fill reservoirs, reducing capacity and eventually end their usefulness.

(5) Heavy pumping of wells near the coast may lead to saltwater intrusion.

(8) Fossil-fuel plants contribute large amounts of materials to the air which precipitation eventually returns to earth Water. used to cool the generators of these plants is returned to the stream at an increased temperature.

(6) Sewage-treatment plants bring sewage effluents back to acceptable levels, but the nutrient content of the treated water is high. This nutrient-rich water hastens eutrophication and stimulates algal bloom downstream.

(7) Intensive development can cause ground-water contamination because of waste disposal problems; close spacing of wells may lead to saltwater intrusion.

Source: Mazzaferro and others, 1979

Figure 8.—The effect of man's activities on water quality

dissolved solids falling on each acre of land with every inch of rain. A significant percentage of the dissolved-solids concentration in streams at high flow is derived directly from atmospheric precipitation.

QUALITY OF RUNOFF

The quality of runoff is determined by the composition of precipitation, the type of earth materials it comes in contact with, and the duration of contact. During high flow, most stream water is derived from direct runoff and contains dissolved constituents similar to those of precipitation. It has a lower concentration of dissolved solids and lower pH than water at low flow. During low flow, most stream water is derived from more highly mineralized ground-water runoff, and therefore dissolved-solids concentration and pH are higher. These relationships are given in table 2, which summarizes dissolved-solids concentration and pH of samples collected from streams draining undeveloped areas.

Water percolating into the ground dissolves more minerals than water flowing over the surface. Thus, ground water generally contains higher concentrations of dissolved solids. The median dissolved-solids concentration of samples from 32 wells tapping coarse-grained stratified-drift deposits and 37 wells tapping crystalline rock were both 116 mg/L, whereas the median value for 30 wells tapping sedimentary rock was 231 mg/L. More detailed information on the quality of surface water and ground water is discussed on p. 52-67.

Table 2.--Dissolved solids and pH in ground water and natural streams[1/]

(Dissolved-solids concentration in milligrams per liter)

		Streams under natural conditions at high flow[2/]	Streams under natural conditions at low flow[3/]	AQUIFERS: Stratified coarse-grained deposits	AQUIFERS: Sedimentary bedrock	AQUIFERS: Crystalline bedrock
Dissolved solids (residue on evaporation at 180°C)	Median	42	61	116	231	116
	Range	23-152	25-288	44-416	96-2,400	31-286
Number of samples		26	26	32	30	37
pH (units)	Median	6.7	6.9	7.1	7.6	7.7
	Range	5.2-8.2	6.0-8.1	6.2-8.4	6.7-8.7	5.7-8.2
Number of samples		26	26	38	30	43

1/ Streams draining relatively undeveloped areas.

2/ Ten percent duration flow.

3/ 90 percent duration flow.

Table 3.--Periods and types of streamflow records at gaging stations

Station no. (Pl. A)	Station name	Drainage area (mi^2)	Type of record	Period of record (water years)
01192700	Mattabessett River at East Berlin	46.5	Continuous and peak flow	1961-72 1973-76
01192800	Parmalee Brook near Durham	2.79	Peak flow	1961-79
01192890	Coginchaug River at Rockfall	34.7	2/ Continuous	1962-79
01193000	Connecticut River near Middletown	1/ 10,872	2/ Continuous	1966-79
01193050	Connecticut River near Middle Haddam	1/ 10,893	3/ Continuous	1966-79
01193120	Ponset Brook near Higganum	5.72	Peak flow	1962-77
01193130	Candlewood Hill Brook near Higganum	3.84	Low flow	1961-71
01193210	Raymond Brook near Amston	3.52	Low flow	1961-64,1967-71
01193250	Judd Brook near Colchester	3.93	Peak flow	1962-79
01193300	Blackledge River near Gilead	6.75	Peak flow	1961-79
01193500	Salmon River near East Hampton	102	Continuous	1929-79
01193600	Flat Brook near East Hampton	2.31	Low flow	1961-64,1967-71
01193800	Hemlock Valley Brook at Hadlyme	2.62	Continuous	1961-74
01194000	Eightmile River at North Plain	20.1	Continuous and peak flow	1938-66 1967-79
01194500	East Branch Eightmile River near North Lyme	22.3	Continuous	1938-79
01195000	Menunketesuck River near Clinton	11.2	Continuous and monthly discharge	1942-67 1963-66
01195100	Indian River near Clinton	5.64	Low flow	1962-71
01195200	Neck River near Madison	6.55	Continuous	1962-79

1/ Includes drainage upstream from study area
2/ Tidal stage and volume
3/ Auxiliary gage for tidal stage

SURFACE WATER

STREAMS

DATA COLLECTION

This report describes an area of 639 mi^2, including 508 mi^2 of the Connecticut River basin in Connecticut south from the northern margin of the Mattabesset River at Middletown to Long Island Sound. (See index map on back of front cover.) This area is drained by six major streams--Mattabesset, Salmon, Eightmile, and Fall Rivers, Ponset Brook, and Whalebone Creek--which account for 373 mi^2. Included in this report are seven river basins draining directly into Long Island Sound--Patchogue, Menunketesuck, Indian, Hammonasset, East and West Rivers--and many smaller brooks draining a total of 131 square miles. The complete drainage system is shown in figure 1 and also on the plates in the back pocket.

The streamflow passing any point varies continuously and has been recorded on a continuous basis for some streams as long as 40 years. A continuous record of the discharge of the Salmon River near East Hampton (station no. 01193500) is available since July 1928. Eighteen other continuous or partial records for shorter periods are also available (table 3). Locations of stream-gaging stations are shown on plate A. Records of streamflow from their beginning through September 1970 have been published annually in a series of U.S. Geological Survey water supply papers entitled "Surface Water Supply of the United States." Records from October 1960 to September 1964 have also been published as "Surface Water Records of Connecticut," and from October 1964, as "Water Resources Data for Connecticut, part 1." All of these publications are listed under "U.S. Geological Survey" in the "Selected References" at the back of this report.

REGIONAL STREAMFLOW RELATIONS

Streamflow records are the basis for determination of water-supply potential and are used to estimate mean annual flows, duration of flows, frequency and duration of low and high flows, and magnitude and frequency of floods. For the purpose of this study, all records were extended or shortened to 30-year reference periods, beginning in April or October 1930 and ending in March or September 1960, so that comparable estimates could be made for any selected location. Short-term records were adjusted by 1) selecting a long-term site nearby with similar geologic characteristics, 2) comparing the flow-duration and low-flow frequency curves for the long-term site with its concurrent short-term curves, and 3) if the distributions were similar, then the short-term site was adjusted accordingly. The period April 1930 to March 1960 includes the 1930-59 climatic years and October 1930 to September 1960, the 1931-60 water years. This reference period conforms with the practice recommended by the World consistent with previous reports in this series. Duration of flows and frequency and duration of low flows during this 30-year period of record were adjusted to the statewide average mean annual streamflow for the reference period, 1.16 million gallons per day per square mile, Mgal/d/mi^2 (1.80 cubic feet per second per square mile, $ft^3/s/mi^2$).

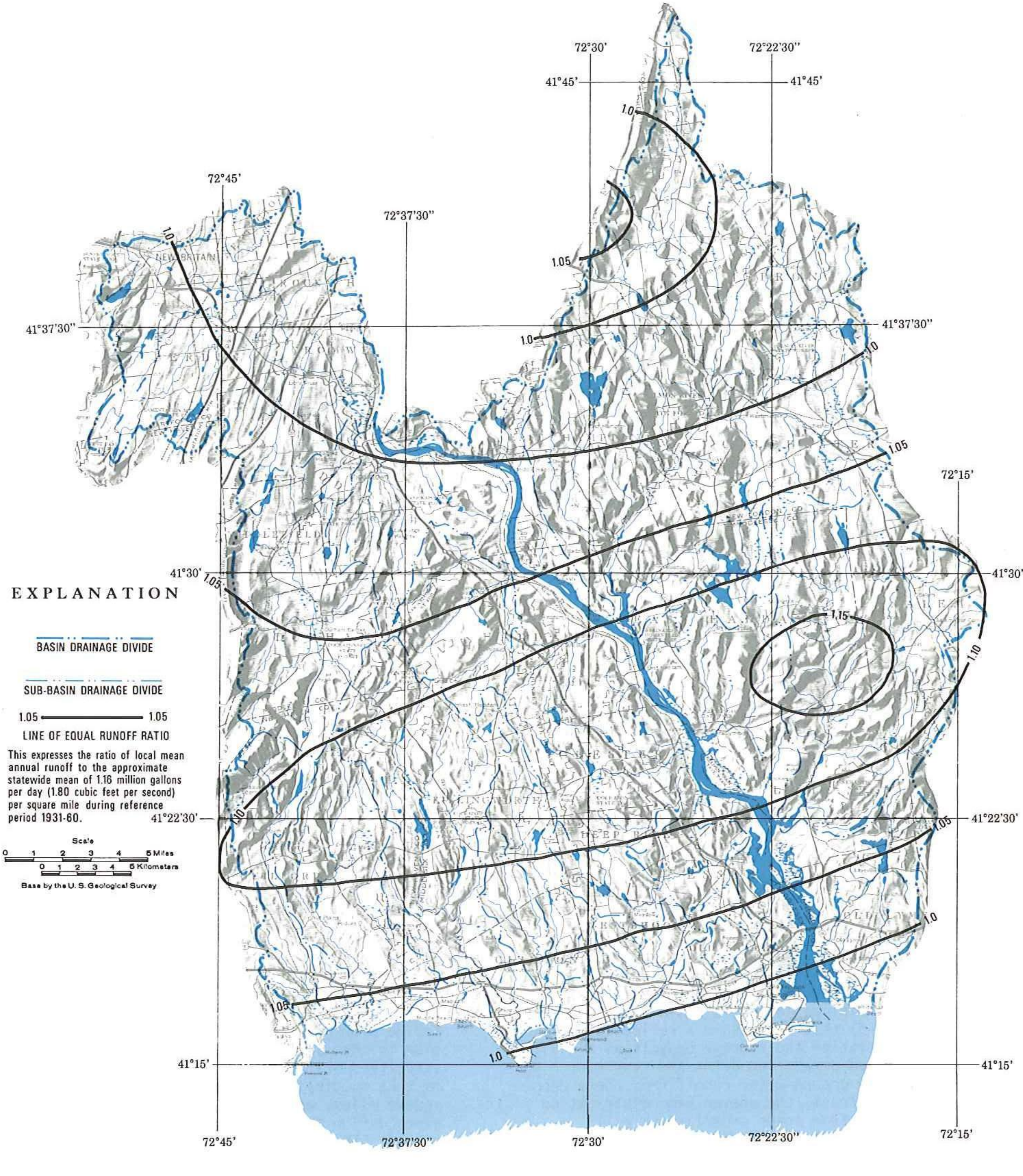


Figure 9.—Areal variation in mean annual runoff

Regional relationships are used to transfer data for a known site to one where no data exists. These relations may be applied to any site provided that no diversion, regulation, or significant urban development exists upstream. They can also be applied to the 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 can be adjusted similarly.

A report on the natural drainage areas of streams and lakes in Connecticut (Thomas, 1972) provides information on the sizes of drainage areas at specific sites.

MEAN ANNUAL FLOW

The discharge passing a point depends upon size and topography of the upstream drainage area, precipitation, evapotranspiration, surface and ground-water storage, and the influence of man on the system. The areal variation in the mean annual runoff of unregulated streams--streams with discharges not affected by upstream controls such as dams, reservoirs, and consumptive diversions--is shown by lines of equal streamflow ratio (figure 9). These lines represent the ratio of local mean annual runoff to the average statewide value of 1.16 million gallons per day per square mile (1.80 cubic feet per second per square mile) for the reference period water years 1931-60. To determine the amount of streamflow at a specific site, use a weighted average ratio representative of the entire upstream drainage area.

FLOW DURATION CURVES

Flow-duration curves show the average percentage of time that specific daily or weekly flows are equaled or exceeded at sites where continuous records of flow are available. Figure 10 shows the duration curve of average weekly flows of the Connecticut River at Middle Haddam for the 1930-58 water years. Flow-duration curves for four stream-gaging stations, calculated for the 1931-60 water years, are shown in figures 11 to 14. The minimum and maximum limits of duration in a single year are also included.

In general, streamflow from areas having a large proportion of coarse-grained stratified drift is more evenly distributed in time than streamflow from areas mantled largely by till. This is graphically represented by a family of regional flow-duration curves developed by Thomas (1966) from statewide data. They show the effect of the surficial geology of a basin on flow duration (fig. 15) that is in turn a reflection of the large infiltration and storage capacities of coarse-grained stratified drift and resultant high proportion of ground-water runoff from these deposits. In contrast, the uneven time distribution of streamflow from areas underlain by till reflects the small infiltration and storage capa-

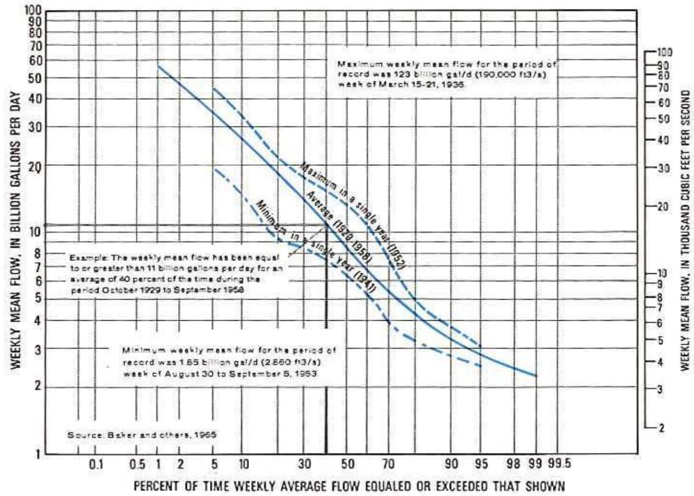


Figure 10.--Duration of average weekly flow of the Connecticut River at Middle Haddam

cities of these deposits and the resultant large proportion of surface runoff.

Extensive areas dominantly underlain by fine-grained stratified drift (clay, silt, and very fine sand) in the Mattabesset River basin (formerly sites of glacial lakes), like till areas, have a low infiltration capacity and most runoff is overland to streams. Flow-duration curves, for streams draining areas underlain by these lake-bottom deposits, are shown in figure 16. They are based on data from the North and South Branches of the Park River in the upper Connecticut River basin, and adjusted to the state-wide average for the 30-year reference period. Areas of coarse- and fine-grained stratified drift in the study area are shown separately on plate B.

The flow-duration curves for coarse-grained stratified drift shown in figure 15 apply only to unregulated streams and are adjusted to a mean annual streamflow of 1.16 $Mgal/d/mi^2$ (1.80 $ft^3/s/mi^2$), the statewide average for the reference period 1930-60. They may be used with figure 9 and the curves of figure 15 to estimate flow-duration curves for ungaged sites on unregulated streams. For example, assume that an average flow-duration curve is needed for the period 1930-60 for a site with a drainage area of 6.0 square miles, of which 1.8 square miles, or 30 percent of the total, consists of coarse-grained stratified drift. The site is assumed to be located where the mean annual discharge from the drainage area (from fig. 9) is 1.06 times the statewide average. The flow-duration curve for this site is that shown in figure 15 for 30-percent stratified drift. Values of flow from this curve must be multiplied by the drainage area, 6.0 square miles, and by the ratio 1.06 to give the average-flow duration curve at this site for the period. The result is tabulated below:

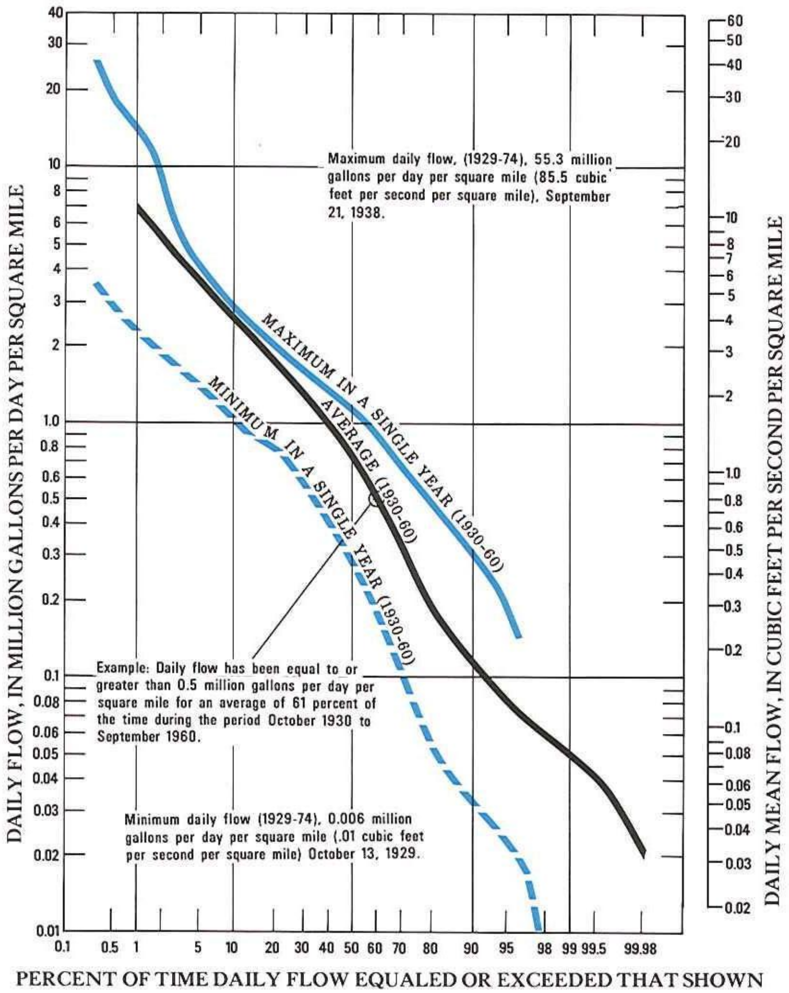


Figure 11.--Daily flow duration of Salmon River near East Hampton

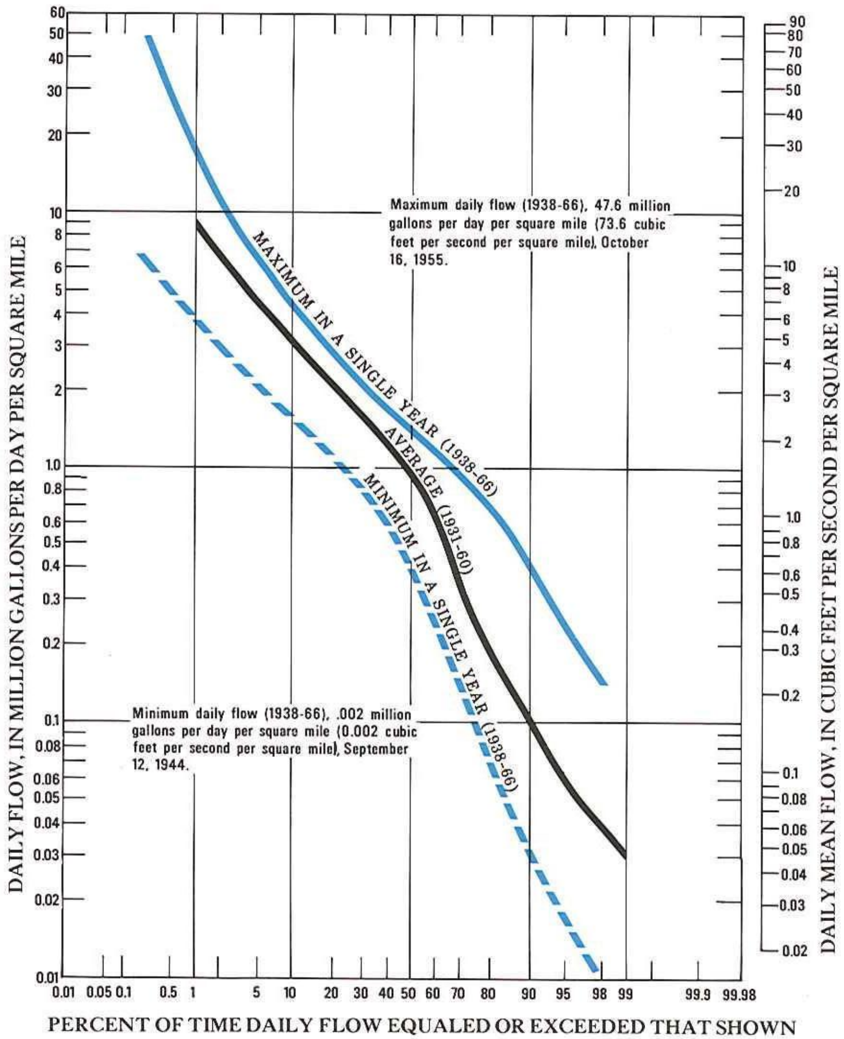


Figure 12.—Daily flow duration of Eightmile River at North Plain

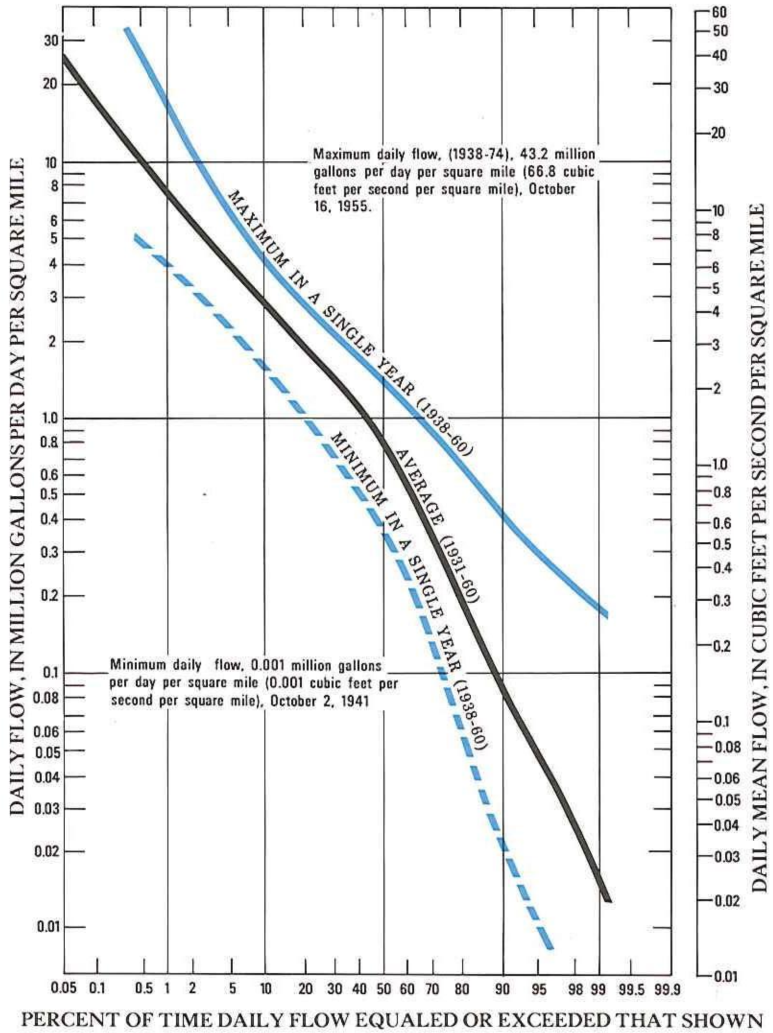


Figure 13.—Daily flow duration of East Branch Eightmile River near North Lyme

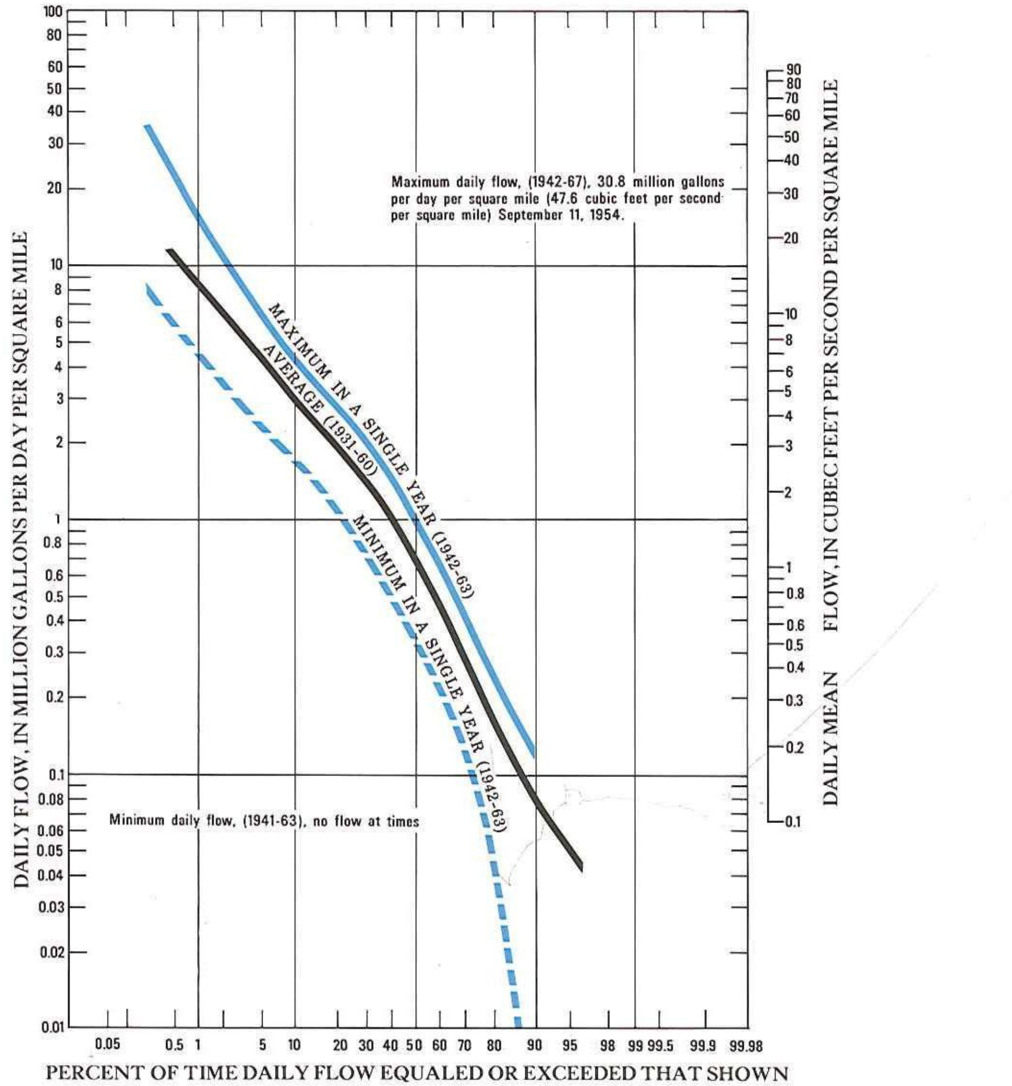


Figure 14.—Daily flow duration of Menunketusuck River near Clinton

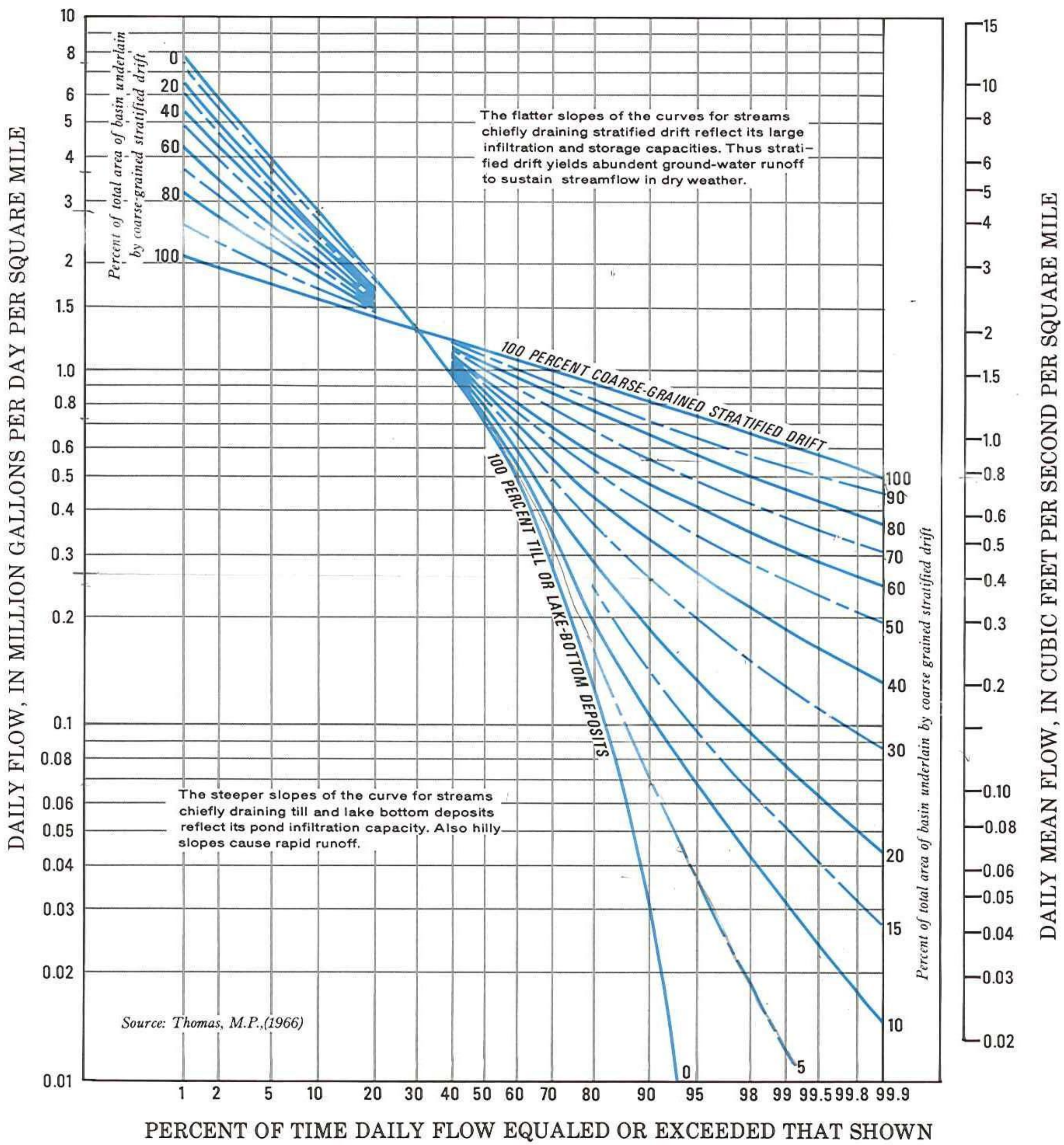


Figure 15.—Relation of duration of mean daily streamflow to percentage of coarse-grained stratified drift underlying the basin

Percent of time	1	5	10	30	50	70	90	95	99
Average flow equaled or exceeded for period 1930-60, in Mgal/d	38	21	15	8.3	5.5	3.2	1.7	1.3	.85

Maximum and minimum flow-duration curves for single years may be estimated by the relationships shown in figure 17. For example, if the flow of 3.2 Mgal/d were equaled or exceeded 70 percent of the time on the average flow-duration curve shown in the table, then during the driest year of the period this flow was probably equaled or exceeded 50 percent of the time, and during the wettest year, 90 percent of the time. These curves can be used to estimate water availability during wet- and dry-year extremes for reservoir design and induced infiltration to ground-water pumpage.

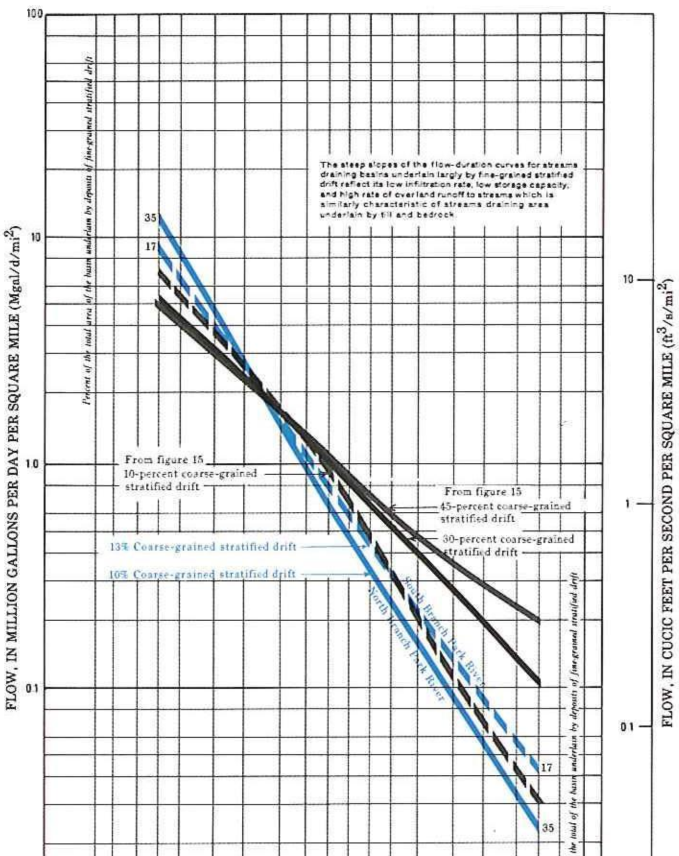


Figure 16.--Relation of duration of mean daily streamflow to percentage of fine-grained stratified drift underlying the basin

Any diversion or regulation upstream from a selected site would require adjustments to the natural flow-duration curve.

LOW-FLOW FREQUENCY CURVES

Occurrences of low flow are best shown by frequency curves of annual lowest mean flows for various periods of consecutive days as derived from long-term streamflow-gaging stations.

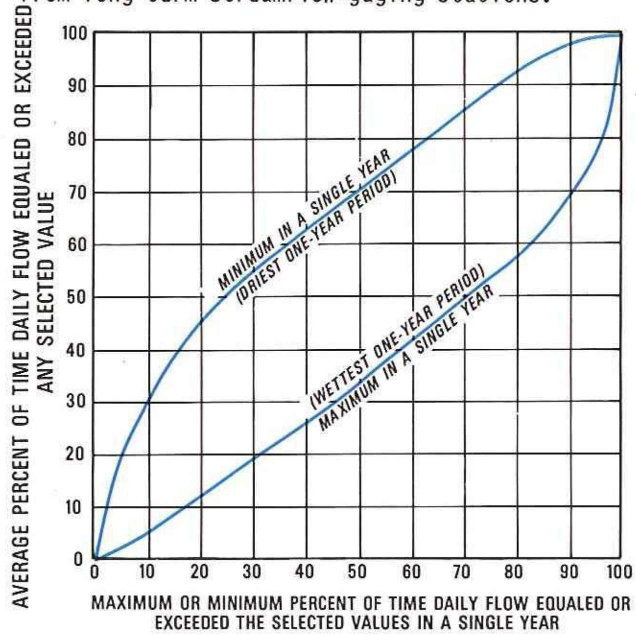


Figure 17.--Range in duration of streamflow, 1931-60 water years

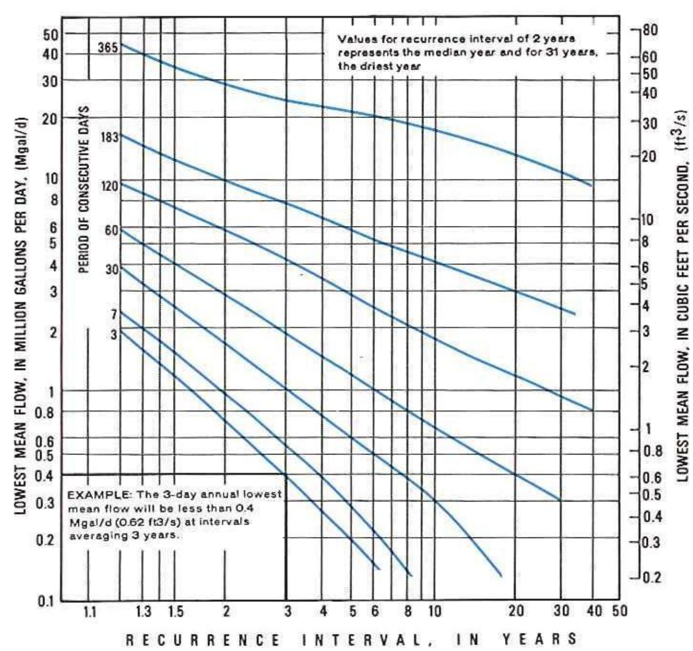


Figure 18.--Low-flow frequency curves of East Branch Eightmile River near North Lyme, April 1930 to March 1960

Commonly used indices of low flow are: 1) the lowest annual mean flow for 30 consecutive days having a recurrence interval of 2 years (30-day, 2-year low flow), and 2) the 7-consecutive-day flows having an average recurrence interval of 10 years (7-day, 10-year low flow). Techniques for describing low-flow frequency have been described by Riggs (1968).

Frequency characteristics of low flows at five long-term streamflow-gaging stations, for the reference period April 1930-March 1960, are given in table 4. A graphic representation is shown in figure 18 for the stream-gaging station on the East Branch of Eightmile River near North Lyme. Relations between points on duration curves and points on low-flow frequency curves for this area are given in table 5.

Table 4.--Annual lowest mean flows for indicated periods of consecutive days and indicated recurrence intervals at long-term stream-gaging stations

(Flows are adjusted to the reference period April 1930 to March 1960.)

Station No.	Stream and location	Drainage area (mi^2)	Period of consecutive days	Annual lowest mean flow (ft^3/s) for indicated recurrence intervals in years							Annual lowest mean flow ($Mgal/d/mi^2$) for indicated recurrence intervals in years						
				1.2	2	3	5	10	20	31	1.2	2	3	5	10	20	31
01193050	Connecticut River at Middle Haddam	10,893[1/]	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			7	4,700	3,800	3,500	3,300	3,000	2,800	2,750	-	-	-	-	-	-	-
			30	5,600	4,400	4,100	3,700	3,400	3,300	3,200	-	-	-	-	-	-	-
			60	7,100	5,400	4,900	4,400	4,000	3,600	3,400	-	-	-	-	-	-	-
			120	8,800	6,400	5,800	5,200	4,600	4,300	3,800	-	-	-	-	-	-	-
			183	12,500	8,700	7,800	7,000	6,000	5,200	4,800	-	-	-	-	-	-	-
01193500	Salmon River near East Hampton	102	3	15	10	7.9	6.0	4.3	3.0	2.6	0.09	0.064	0.050	0.038	0.027	0.019	0.017
			7	18	12	9.2	7.1	5.1	3.7	3.0	.12	.076	.058	.045	.032	.024	.019
			30	26	17	13	10	7.2	5.2	4.3	.17	.11	.082	.064	.046	.033	.027
			60	36	24	18	14	10	7.2	6.0	.23	.16	.12	.088	.064	.046	.038
			120	66	43	33	26	18	13	11	.42	.27	.21	.17	.12	.082	.070
			183	105	70	54	42	30	22	18	.67	.44	.34	.26	.19	.14	.12
			365	219	164	140	117	92	74	66	1.39	1.04	.88	.75	.58	.47	.42
01194000	Eightmile River at North Plain	20.1	3	2.3	1.3	.9	.7	.5	.4	.3	0.07	.04	.03	.02	.01	.01	.01
			7	3.0	1.6	1.2	.9	.6	.4	.4	.09	.05	.04	.03	.02	.01	.01
			30	5.0	2.6	1.8	1.3	.9	.7	.6	.16	.08	.06	.04	.03	.02	.02
			60	7.8	3.7	2.6	1.9	1.3	.9	.8	.25	.12	.08	.06	.04	.03	.02
			120	14	7.1	5.0	3.7	2.6	2.0	1.5	.45	.23	.16	.12	.08	.06	.05
			183	22	12	9.3	7.1	5.2	4.3	3.5	.70	.39	.30	.23	.17	.14	.11
			365	54	43	39	32	24	18	15	1.74	1.39	1.24	1.04	.80	.60	.48
01194500	East Branch Eightmile River near North Lyme	22.3	3	3.1	1.1	.6	.3	.2	.1	.1	0.09	.03	.02	.01	0	0	0
			7	3.7	1.4	.8	.4	.2	.1	.1	.11	.04	.02	.01	0	0	0
			30	5.9	2.6	1.5	.9	.5	.2	.2	.17	.08	.04	.03	.01	0	0
			60	8.8	4.4	2.9	1.8	1.0	.6	.4	.26	.13	.09	.05	.03	.02	.01
			120	15	8.8	6.6	4.4	2.6	2.1	1.3	.43	.26	.19	.13	.08	.06	.04
			183	24	15	12	8.8	5.9	4.8	3.3	.72	.43	.35	.26	.17	.14	.10
			365	68	44	37	31	26	20	16	1.97	1.26	1.08	.90	.76	.58	.45
01195000	Menunketesuck River near Clinton	11.2	3	1.4	.9	.6	.3	.2	.1	.1	0.08	.05	.04	.02	.01	.01	.01
			7	1.8	1.1	.7	.4	.2	.1	.1	.11	.06	.04	.03	.01	.01	.01
			30	2.5	1.4	1.0	.6	.3	.2	.1	.14	.08	.05	.04	.02	.01	.01
			60	3.9	2.2	1.6	1.1	.6	.3	.2	.22	.12	.09	.06	.04	.02	.01
			120	8.4	4.9	3.5	2.4	1.6	1.1	.8	.48	.29	.21	.14	.09	.06	.04
			183	11	7.1	5.4	4.2	3.0	2.2	1.9	.63	.41	.31	.24	.17	.12	.11
			365	34	24	20	16	13	11	10	1.96	1.43	1.16	.89	.75	.63	.58

1/ Includes drainage upstream from report area

Table 5.--Average duration of lowest mean flows

(As a percentage of time; based on records from April 1930 to March 1960 at 34 continuous-record gaging stations throughout Connecticut)

Period of low flow in consecutive days	Average percent of time in which streamflow equaled or exceeded the lowest mean flow for indicated recurrence interval (years)						
	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

Example shows that for any site on an unregulated stream, the 30-consecutive-day 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.

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 for 7, 15, 30, 60, and 120 consecutive days, for the period of record, at six long-term stream-gaging stations, and the climatic year that they occurred, are given in table 6.

ANNUAL HIGH-FLOW FREQUENCY CURVES

Annual high-flow frequency curves are used for design of storage required for flood control. The recurrence intervals of highest annual mean flows for various periods of consecutive days at four long-term gaging stations are given in table 7.

Table 6.--Annual lowest mean flows for indicated consecutive days at long-term stream-gaging stations

Station no. (pl. A)	Stream and location	Period of record	Drainage area (mi^2)	Lowest mean flow (cfs) for indicated periods of consecutive days and water year in which it occurred: 7-day	year	14-day	year	30-day	year	60-day	year	120-day	year
01193050	Connecticut River at Middle Haddam 1/	1929-58	2/10,893	2,860	1953	3,050	1953	3,290	1930	3,440	1953	4,020	1953
01193500	Salmon River near East Hampton	1930-60	102	3.7	1930	5.1	1930	5.1	1930	7.2	1957	8.4	1957
01193800	Hemlock Valley Brook at Hadlyme	1961-70	2.62	.14	1963	.15	1963	.23	1966	.27	1966	.43	1966
01194000	Eightmile River at North Plain	1938-60	20.1	.2 .2	1943 1943	.3 .3	1943 1943	.4 .4	1943 1943	-	-	-	-
01194500	East Branch Eightmile River near North Lyme	1939-60	22.3	.16	1944	.23	1944	.30	1944	.74	1943	1.9	1957
01195000	Menunketesuck River near Clinton	1942-60	11.2	.05	1943	.08	1943	.10	1943	.24	1943	1.0	1956

1/ After Baker, J. A. (1965).
2/ Includes drainage upstream from report area

Table 7.--Annual highest mean flows for indicated periods and recurrence intervals.

(Shown for four long-term gaging stations based on data for period of record.)

Station No. (pl. A)	Stream and location	Drainage area (mi^2)	Datum (ft above msl)	Period of record (water years)	Period of consecutive days	Annual highest mean flow (ft^3/s) for indicated recurrence interval (years): 1.03	2	5	10	25	50	100
01193500	Salmon River near East Hampton	102	66.51	1929-70	0	980	2,500	4,000	5,600	7,800	9,800	12,000
					1	695	1,650	2,650	3,450	4,650	5,750	7,000
					3	545	1,150	1,700	2,150	2,800	3,350	3,950
					7	425	795	1,100	1,350	9,700	2,000	2,300
					15	340	580	785	935	1,150	1,300	1,500
					30	270	470	610	710	835	930	1,050
					60	230	385	485	550	625	680	735
					120	180	315	390	430	475	500	530
					183	145	270	335	370	410	430	455
					365	90	170	215	240	270	290	310
0119400	Eightmile River at North Plain	20.1	57.74	1938-66	0	305	700	1,050	1,450	1,950	2,400	2,900
					1	210	325	595	730	930	1,100	1,300
					3	140	275	395	490	620	735	855
					7	105	190	265	325	405	470	540
					15	85	135	180	215	265	310	355
					30	65	105	140	160	195	220	245
					60	50	85	110	125	145	155	170
					120	45	70	185	100	110	120	125
					183	35	60	75	85	95	100	105
					365	20	35	45	55	60	65	70
01194500	East Branch Eightmile River near North Lyme	22.3	55.21	1938-70	0	270	620	750	1,250	1,700	2,100	2,500
					1	225	440	630	760	955	1,120	1,290
					3	170	300	405	485	590	680	775
					7	130	210	275	325	390	440	495
					15	100	155	195	225	260	295	325
					30	80	120	150	170	195	215	235
					60	65	95	120	130	150	160	775
					120	50	80	95	110	120	130	140
					183	40	70	85	90	100	110	115
					365	25	40	50	60	65	70	75
01195000	Menunketesuck River near Clinton	11.2	23.64	1942-63	0	180	420	650	890	1,200	1,500	1,850
					1	135	255	370	455	580	690	805
					3	85	165	225	275	335	385	440
					7	65	115	150	175	210	235	260
					15	55	80	100	115	130	145	155
					30	40	65	80	90	105	115	125
					60	35	50	60	70	75	85	90
					120	30	40	50	55	65	70	75
					183	20	35	40	45	50	55	60
					365	13	22	25	29	32	33	35

Table 8.—Available data for selected lakes, ponds, and reservoirs

(Safe regulated flows for the reference period April 1930 to March 1960. Lakes, ponds, and reservoirs will refill within a year.)

Sta. no. (pl. A)	Name and location	Drainage basin	Source of data [1]	Natural (N) or artificial (A) [2]	Drainage area (mi²)	Surface area (acres)	Surface elevation (ft above sea level)	Average depth (ft)	Storage Total (Mgal)	Storage Usable (Mgal)	Maximum safe regulated flow, Driest year (ft³/s)	Maximum safe regulated flow, Driest year (Mgal/d)	Maximum safe regulated flow, Median year (ft³/s)	Maximum safe regulated flow, Median year (Mgal/d)	Principal use	Types of water-quality data available
01192680	Hallmere Reservoir near Berlin	Mattabesset River	Mo	A	1.05	16	329	26.8	140	-	3/ 0.66	3/ 0.43	1.81	1.17	Water supply	4/
01192681	Kenmere Reservoir near Berlin	Mattabesset River	Mo	A	2.17	22	225	18.5	133	-	3,5/1.65	3,5/1.05	3,5/3.78	3,5/2.44	Water supply	4/
01192682	Merimere Reservoir near Berlin	Mattabesset River	Mo	A	.58	44	394	24.8	357	-	-	-	-	-	Water supply	4/
01192685	Silver Lake near Berlin	Mattabesset River	Fg	A	1.92	151	150	4.5	222	222	3/ 2.16	3/ 1.40	3/ 1.40	3/ 2.24	Recreation	-
01192688	Wasel Reservoir (Panther Swamp) near New Britain	Mattabesset River	Nb	A	.32	103	512	26.7	900	800	-	-	-	-	Water supply	4/
01192689	Shuttle Meadow Reservoir near New Britain	Mattabesset River	Nb	A	3.17	205	373	19.2	1290	1000	3/ 1.84	3/ 1.19	3/ 5.23	3/ 3.38	Water supply	4/
01192725	Mount Higby Reservoir near Middlefield	Coginchaug River	Mi	A	1.40	122	363	8.9	354	354	3/ .82	3/ .53	3/ 2.38	3/ 1.54	Water supply	4/
01192730	Roaring Brook Reservoir near Middlefield	Coginchaug River	Mi	A	.58	303	495	2.0	20	20	-	-	-	-	Water supply	-
01192880	Besek Lake at Middlefield	Coginchaug River	Fg	A	1.95	120	315	11.2	438	438	3/ 1.25	3/ .81	3/ 3.34	3/ 2.16	Recreation, Industrial	4,6,7/
01192889	Laurel Brook Reservoir near Middlefield	Coginchaug River	Mi	A	1.11	62.4	219	10.9	223	223	3/ .73	3/ .47	3/ 1.89	3/ 1.22	Water supply	4/
01192912	Miller Pond near Durham	Sumner Brook	MSPR	A	.40	303	560	10.0	99	99	-	-	-	-	Recreation	-
01192960	Dooley Pond near Middletown	Sumner Brook	Fg	A	.59	28	249	4.9	44.8	44.8	-	-	-	-	Recreation	6/
01192925	Pameacha Pond near Middletown	Sumner Brook	Fg	A	4.25	20.5	75	7.7	52.5	52.5	.75	.48	2.15	1.39	Recreation	4/
01192930	Crystal Lake near Middletown	Sumner Brook	Fg	A	.27	35.5	180	7.9	91.1	91.1	-	-	-	-	Recreation	6/
01193010	Great Hill Pond near Portland	Connecticut River	Fg	A	1.22	77.5	309	5.5	139	-	3/ .72	3/ .46	1.90	1.23	Recreation	-
01193125	Higganum Reservoir near Haddam	Ponset Brook	Fg	A	6.73	32	98	12.6	131	131	2.95	1.91	5.56	3.60	Recreation	6/
01193131	Scoville Reservoir near Ponset	Ponset Brook	MSPR	A	.29	21.1	450	10.7	74	74	-	-	-	-	Recreation	-
01193200	Holbrook Pond near Hebron	Salmon River	Fg	A	1.84	72.5	522	3.9	91.6	-	.83	.54	1.68	1.09	Recreation	6/
01193270	Babcock Pond near Westchester	Salmon River	Fg	A	2.90	147	379	2.8	134	134	2.14	1.39	3.59	2.32	Recreation	-
01193470	Terramugus Lake near Marlborough	Salmon River	N	N	.54	83	454	21.4	57.9	-	-	-	-	-	Recreation	4,6/
01193480	Strong Pond near East Hampton	Salmon River	MSPR	A	3.22	28.5	425	5.0	47	-	.64	.41	1.56	1.01	Recreation	-
01193650	Lake Pocotopaug at East Hampton	Salmon River	Fg	NA	4.52	512	465	11.3	1870	-	3/ 2.58	3/ 1.67	3/ 7.45	3/ 4.82	Recreation	-
01193720	Bashan Lake near Moodus	Salmon River	Fg	NA	1.99	276	386	15.9	1440	1440	3/ 1.26	3/ .81	3/ 3.58	3/ 2.32	Recreation	6/
01193721	Pickerel Pond near Moodus	Salmon River	Fg	A	1.39	88.6	425	6.0	175	175	3/ .83	3/ .54	3/ 2.41	3/ 1.56	Recreation, Industrial	6/
01193722	Moodus Reservoir near Moodus	Salmon River	Fg	A	10.5	451	357	5.0	737	737	3,8/8.90	3/ 5.76	3,8/18.9	3,8/12.2	Recreation, Industrial	6/
01193760	Upper Pond near Tylerville	Clark Creek	C	A	.22	6.2	295	5.9	12	9	-	-	-	-	Water supply	-
01193790	Waterhouse Pond near Chester	Waterhouse Brook	C	A	.26	47.1	293	12.3	190	120	-	-	-	-	Water supply	-
01193850	Pataconk Reservoir near Chester	Chester Creek	Fg	A	1.84	55.5	322	10.3	187	187	3/ 1.32	3/ .85	3/ 2.97	3/ 1.92	Recreation, Industrial	6/
01193860	Cedar Lake near Chester	Chester Creek	Fg	NA	3.23	68	241	19.3	428	-	3,9/2.66	3,9/1.72	3,9/6.12	3,9/3.95	Recreation	6/
01193865	Turkey Hill Reservoir near West Haddam	Chester Creek	Fg,C	A	1.20	80.4	310	5.7	149	149	-	-	-	-	Water supply	6/
01193866	Deep Hollow Reservoir near Chester	Chester Creek	C	A	3.94	24.9	231	8.0	65	65	-	-	-	-	Water supply	-
01193867	Deuces Pond near Chester	Chester Creek	C	A	4.28	3.4	150	5.4	6	6	10/2.68	10/1.73	10/5.00	10/ 3.23	Water supply	-
01193900	Lake Hayward near Millington	Eightmile River	Fg	NA	2.49	190	348	10.0	621	-	3/ 2.19	3/ 1.42	3/ 4.66	3/ 3.02	Recreation	6,7/
01194700	Norwich Pond near Hamburg	Eightmile River	Fg	NA	.48	27.5	100	22.9	206	-	-	-	-	-	Recreation	-
01194710	Uncas Pond near Hamburg	Eightmile River	Fg	N	1.50	65	49	22.2	502	-	3,11/1.60	3,11/1.03	3,11/2.75	3,11/1.78	Recreation	6/
01194800	Rogers Lake at Laysville	Lieutenant River	Fg	NA	7.53	265	36	20.1	1740	-	3/ 6.25	3/ 4.05	3/ 13.3	3/ 8.60	Recreation	6,7,12,13/
01194980	Killingworth Reservoir near Killingworth	Menunketesuck River	C	A	1.40	80	296	8.5	222	221	-	-	-	-	Water supply	4/
01194990	Kelseytown Reservoir near Killingworth	Menunketesuck River	C	A	10.0	15.4	167	3.8	18.9	18.9	14/3.38	14/ 2.19	14/ 7.33	14/ 4.73	Water supply	4/
01195020	Hammonasset Reservoir near North Madison	Hammonasset River	Nh	A	20.5	377	267	17.1	1400	1080	13.5	8.73	24.3	15.7	Water supply	4/
01195040	Hidden Lake at West Haddam	Hammonasset River	Fg	A	1.23	37.3	514	4.6	56.1	-	.72	.46	1.29	.84	Recreation	-
01195280	Menunkatuck Reservoir at North Guilford		Nh	A	3.71	39.5	253	15.7	203	197	1.87	1.21	3.87	2.50	Water supply	4/
01195281	Lake Quonnipaug at North Guilford		Fg	NA	2.63	112	181	13.6	494	-	3/ 3.23	3/ 1.44	3/ 4.83	3/ 3.13	Recreation	6,7,12,13/

1/ Most data from (C) Connecticut Water Co., (Mo) Meriden Water Dept., (Mi) Middletown Water Dept., (MSPR) Mid-State Planning Region Agency, (NB) New Britain Water Dept.
2/ NA, water body is natural but has water level raised by low dam.
3/ If lakes, ponds, and reservoirs are to refill in a year, all of the usable storage cannot be used.
4/ Chemical and physical water-quality data available at U.S. Geological Survey, Hartford, Connecticut.
5/ Includes storage available from Hallmere Reservoir.
6/ Variation of temperature, dissolved oxygen, and pH, with depth available at State Department of Environmental Protection (DEP), Fish and Water Life Unit.
7/ Measurements of alkalinity versus depth available at DEP, Fish and Water Life Unit.
8/ Includes storage available from Bashan Lake and Pickerel Pond.
9/ Includes storage available from Pataconk Reservoir.
10/ Includes storage available from Turkey Hill and Deep Hollow Reservoirs.
11/ Includes storage available from Norwich Pond.
12/ Measurements of color versus depth available at DEP, Fish and Water Life Unit.
13/ Measurements of chemical constituents versus depth available at DEP, Fish and Water Life Unit.
14/ Includes storage available from Killingworth Reservoir.

Table 9.--Storage required to maintain indicated regulated flows at long-term stream-gaging stations

(Data are adjusted to reference period April 1930 - March 1960. Storage required would refill reservoir during a year except for underlined figures which would require more than a year to refill. Storage is uncorrected for reservoir seepage, evaporation, and for bias in computation procedure, all which would increase the amount of storage required.)

Station No. (pl. A)	Stream and location	Drainage area (mi^2)	Recurrence interval of annual lowest mean flow (years)	Maximum storage needed for refilling during year of lowest mean flow ($Mgal/mi^2$)	Storage required ($Mgal/mi^2$) 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
01193500	Salmon River near East Hampton	102	1.2	-	-	-	1	3	5	8	11	14	18	22	26	30	34	38	42	50	78
			2	-	-	1	3	5	8	12	17	22	28	34	40	47	54	62	70	85	104
			5	87	1	4	8	12	17	23	29	36	44	53	62	72	82	92	102	122	142
			10	73	3	6	10	16	23	31	40	49	58	68	78	88	98	109	121	143	166
			31	54	4	8	14	24	34	43	53	63	73	84	95	106	118	131	145	169	195
01194000	Eightmile River at North Plain	20.1	1.2	-	-	-	1	2	4	6	8	10	13	16	20	24	28	34	40	50	61
			2	-	-	1	4	7	11	15	20	25	30	36	42	48	55	62	70	86	102
			5	-	2	5	9	15	22	29	36	43	50	58	66	74	82	90	99	117	135
			10	127	3	8	14	20	27	34	42	50	58	66	75	84	93	103	113	133	154
			31	73	6	12	19	26	34	42	50	59	68	78	88	98	108	119	130	154	179
01194500	East Branch Eightmile River near North Lyme	22.3	1.2	-	-	-	2	4	6	8	10	12	15	18	22	27	32	37	42	52	62
			2	-	-	-	2	6	10	15	20	25	30	35	40	46	52	59	67	83	102
			5	-	2	6	10	15	20	26	32	39	46	54	62	71	80	89	98	118	139
			10	111	4	9	15	21	28	35	43	51	60	69	78	87	96	105	115	135	157
			31	70	8	14	21	29	38	47	56	65	74	83	92	103	115	127	134	166	196
01195000	Menunketesuck River near Clinton	11.2	1.2	-	-	-	2	3	5	8	11	14	17	20	24	28	32	36	40	52	70
			2	-	-	2	5	8	11	15	19	23	28	34	40	47	55	64	73	92	111
			5	119	3	6	10	14	19	25	32	40	48	57	66	75	84	94	105	125	145
			10	105	4	8	13	19	26	34	43	52	61	70	79	88	98	109	120	142	164
			31	85	5	11	18	26	35	44	53	63	73	83	93	103	114	125	137	159	183

Table 7 shows, for example, that the annual highest mean flow for 30 consecutive days at the 10-year recurrence interval on Salmon River near East Hampton is 710 ft^3/s. Thus, there is a 10-percent chance that a 30-day highest mean flow of 710 ft^3/s will be exceeded in any one year. The instantaneous peak discharge (0 consecutive days) at 10-year recurrence interval is 5,600 ft^3/s. Stations 01193500, 01194000, and 01195000 each have about 12 percent of the area upstream underlain by coarse-grained stratified drift and station 01194500 has 22 percent. The higher the areal percent of coarse-grained stratified drift, the lower the unit runoff at high flow.

STORAGE OF WATER

EXISTING LAKES, PONDS AND RESERVOIRS

Table 8 presents storage information for selected surface-water bodies in the area. The volume of usable water in storage is defined as that which may be withdrawn by gravity through a valve or gate. Water-quality information on the public water supply reservoirs is given in table 30.

DRAFT-STORAGE RELATIONS

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 9 shows the frequency with which various amounts of storage are required to maintain selected rates of regulated flow at long-term stream-gaging stations based on records for 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 9 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.

By relating unit runoff for various flow frequencies to percent of drainage basin underlain by coarse-grained stratified drift, frequency-mass curves can be generated for ungaged sites.

Amount of storage required to maintain various draft rates in previously unregulated streams are presented in table 10. These data are shown for indicated percentages of drainage area underlain by coarse-grained stratified drift. Interpolations between percentages given may be made if necessary. Storage used to provide regulated flow would be replaced within 1 year. Table 9 is based upon an average streamflow of 1.16 $Mgal/d/mi^2$ for the reference period, October 1930 to September 1960. Before table 10 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 that site by using the appropriate ratio determined from figure 9.

The amounts of storage required according to table 10 are smaller than the true values because they include a bias of about 10 percent, which results from the use of the frequency-mass curve. Moreover, losses due to evaporation and seepage from the reservoir are not included. The amounts

Table 10.--Storage required to maintain indicated regulated flows at sites on unregulated streams related to surficial geology

(Data are adjusted to the reference period April 1930 - March 1960 and to an average streamflow of 1.16 Mgal/d/mi^2. Storage required would be replenished within a year. Storage is uncorrected for reservoir seepage, evaporation, and for bias in computation procedure, all of which increase the amount of storage required.)

Percent of area covered by coarse-grained stratified drift	Recurrence interval of annual lowest mean flow (years) 1/	Maximum amount of storage which would be replenished during the year of lowest annual flow (Mgal/mi^2)	Storage required (Mgal) 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	1.0
0																			
	2	144	3	7	12	17	23	30	37	45	53	61	69	77	86	95	104	124	–
	5	94	8	14	22	30	39	48	57	67	77	87	–	–	–	–	–	–	–
	10	69	11	19	28	37	46	56	66	–	–	–	–	–	–	–	–	–	–
	31	46	15	27	38	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10																			
	2	–	–	2	4	7	10	15	20	26	33	40	48	56	64	73	82	100	118
	5	91	2	6	11	17	24	32	40	49	58	68	78	88	–	–	–	–	–
	10	76	5	11	17	24	32	42	52	62	72	–	–	–	–	–	–	–	–
	31	58	6	15	25	35	46	57	–	–	–	–	–	–	–	–	–	–	–
20																			
	2	–	–	–	–	2	5	8	12	17	22	29	36	43	50	57	65	81	98
	5	87	–	–	3	7	13	19	26	34	42	51	60	68	76	86	–	–	–
	10	77	–	2	6	11	19	27	35	44	54	64	74	–	–	–	–	–	–
	31	63	–	4	11	20	30	40	50	60	–	–	–	–	–	–	–	–	–
30																			
	2	–	–	–	–	–	1	3	6	10	14	19	24	30	37	44	51	68	86
	5	78	–	–	–	1	4	8	14	20	27	34	42	50	59	69	–	–	–
	10	65	–	–	1	4	8	14	20	28	36	44	53	62	–	–	–	–	–
	31	57	–	–	2	8	14	23	32	41	51	–	–	–	–	–	–	–	–
40																			
	2	–	–	–	–	–	–	–	2	5	8	11	15	20	25	31	38	53	69
	5	73	–	–	–	–	1	3	6	10	15	21	29	37	45	53	61	–	–
	10	64	–	–	–	–	2	6	11	17	24	32	40	48	57	65	74	–	–
	31	57	–	–	–	1	6	12	19	27	36	45	55	–	–	–	–	–	–
50																			
	2	–	–	–	–	–	–	–	–	–	2	4	7	11	16	22	28	43	59
	5	68	–	–	–	–	–	–	1	3	6	11	16	22	29	37	46	67	–
	10	58	–	–	–	–	–	–	3	7	12	27	24	32	40	49	58	–	–
	31	51	–	–	–	–	–	2	7	13	20	29	37	45	–	–	–	–	–
60																			
	2	–	–	–	–	–	–	–	–	–	–	1	4	6	9	12	18	32	48
	5	61	–	–	–	–	–	–	–	–	2	5	8	13	19	25	32	50	–
	10	55	–	–	–	–	–	–	–	1	4	9	14	20	27	35	43	–	–
	31	50	–	–	–	–	–	–	1	4	9	15	22	30	38	48	–	–	–
80																			
	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	4	12	23
	5	–	–	–	–	–	–	–	–	–	–	–	–	–	2	5	10	22	37
	10	–	–	–	–	–	–	–	–	–	–	–	–	1	4	8	15	30	48
	31	43	–	–	–	–	–	–	–	–	–	–	1	5	10	17	24	41	–
100																			
	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11
	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16
	31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	26

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

shown in table 10 are sufficiently accurate for preliminary planning and for tentative site selection. Furthermore, regulated flow rates assume continuous use and may be increased proportionately if use is intermittent.

Following is an example for a site with a drainage area of 6.0 square miles, 30 percent of which is covered by stratified drift, and located where the mean annual streamflow is 1.06 times the statewide average. To determine the amount of storage required to maintain a regulated flow of 2.3 Mgal/d at this site, 1) divide 2.3 Mgal/d by the drainage area of 6.0 square miles, which results in a unit-regulated flow of 0.383 Mgal/d/mi^2; 2) for a drainage area 30 percent of which is covered by stratified drift, a recurrence interval of 31 years (driest year), and a regulated flow of 0.383 Mgal/d/mi^2, by interpolation in table 10, the required storage is 27.3 Mgal/d/mi^2; 3) adjusting for the statewide average mean annual flow (28.9 Mgal/mi^2 $\div$ 1.06), or a total of 164 million gallons for 6.0 square miles (27.3 x 6.0); and 4) adjusting for bias, evaporation, and seepage raises this to about 180 million gallons.

FLOODS

HISTORY

Floods have occurred in the study area in every month of the year. Spring flooding is the most common and usually results from the combined effects of rapid snowmelt and rain, whereas summer and fall flooding is commonly the result of hurricanes. Peak stages of the Connecticut River at Hartford were recorded as early as 1639 (Kinnison, 1938) and have been recorded continuously since 1843. Annual peak stages and discharges of the Connecticut River at Middletown were recorded in 1814, 1848, 1854, 1860, 1861, 1927, 1936, 1938, and continuously since 1947. Following the disastrous floods of March 1936 (the highest of record) and September 1938 (the second highest) several flood-control reservoirs were constructed in the headwaters, and channel improvements were made so that now about 1,580 mi^2 of the total drainage area of 10,882 mi^2, north of Middletown, are controlled by flood detention facilities. These reservoirs have significantly reduced peaks.

Notable floods have also occurred on the tributaries of the Connecticut River. The highest, since crest-stage measurements were first made on the Salmon River at East Hampton in July 1928, was the hurricane-caused flood of September 1938. The flood of September 1954 was also especially severe in the southern part of the basin and that of August 1955 in the western part.

General descriptive information concerning major floods in New England through 1955 is given by Thomson and others (1964). More detailed records of the major floods of 1936, 1938, 1955, and 1956, based primarily on gaging-station records, are given by Grover (1937), Paulsen and others (1940), the U.S. Geological Survey (1947), and Bogart (1960). Green (1964) has compiled flood peaks above selected magnitudes for continuous-record gaging stations through September 1960.

Maximum recorded flood peaks at gaging stations within the report area are listed in table 11.

MAGNITUDE AND FREQUENCY

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 magnitudes and frequencies of flood-peak discharges at five long-term gaging stations, based on the period 1930-71, is given in table 12. For preliminary planning purposes at most other sites, peak discharges may be estimated by use of figures 19 and 20, provided that the streams are unregulated and unaffected by storm sewers, and have a drainage area of 2 mi^2 or more, and have less than 4.5 million cubic feet of storage per square mile of drainage area. Results are available from studies that relate peak discharge to basin geometry (Bigwood and Thomas, 1955) and to basin geometry and storm sewering (Weiss, 1975).

The median annual peak discharge has a 50-percent chance of being exceeded in any year and may be estimated from figure 19, if the drainage area is known. Peak discharges for other recurrence intervals, up to 100 years (1-percent

Table 11.--Maximum recorded flood peaks and median annual floods at stream-gaging stations

Station No. (Pl. A)	Stream and location	Drainage area (mi^2)	Period of record (water years)	Maximum flood peak of record: Date	Elevation (ft above sea level)	Flow (ft^3/s)	Flow ($ft^3/s/mi^2$)	Median annual flood peak (ft^3/s)	Median annual flood peak ($ft^3/s/mi^2$)	Ratio of maximum peak to median annual flood peak
01192700	Mattabesset River at East Berlin	46.5	1961-70	Feb. 3, 1970	22.85	2,980	64.1	1,740	37.4	1.71
01192800	Parmalee Brook near Durham	2.79	1961-70	-	-	200	71.1	200	71.7	1.00
01192890	Coginchaug River at Rockfall	34.7	1962-70	Feb. 3, 4, 1970	66.36	1,280	36.9	850	24.5	1.51
01193000	Connecticut River near Middletown	10,882 1/	1947-70	Mar. 21, 1936	28.20	267,000	24.6	94,000	8.65	2.84
01193010	Great Hill Pond at Cobalt	1.3	-	Sept. 21, 1938	-	196	151	-	-	-
01193040	Mine Brook at Middle Haddam	1.6	-	Sept. 21, 1938	-	628	392	-	-	-
01193120	Ponset Brook near Higganum	5.72	1962-70	Apr. 2, 1970	-	400	69.9	230	40.2	1.74
01193250	Judd Brook near Colchester	3.93	1962-70	Feb. 3, 1970	-	230	58.5	136	34.6	1.69
01193300	Blackledge River near Gilead	6.75	1961-70	Feb. 3, 1970	-	300	44.4	160	23.7	1.87
01193500	Salmon River near East Hampton	102	1929-70	Sept. 21, 1938	80.46	12,400	122	2,490	24.4	5.00
01193800	Hemlock Valley Brook at Hadlyme	2.62	1961-70	Mar. 6, 1963	40.65	270	100	120	45.8	2.18
01194000	Eightmile River at North Plain	20.1	1940-70	Oct. 15, 1955	65.46	2,350	117	700	34.8	3.36
01194500	East Branch Eightmile	22.3	1938-70	Sept. 21, 1938	61.21	2,950	132	620	27.8	4.75
01195000	Menunketesuck River near Clinton	11.2	1942-67	Sept. 11, 1954	32.15	1,500	134	425	37.9	3.54
01195200	Neck River at Madison	6.55	1962-70	July 30, 1969	12.66	194	29.6	150	22.9	1.29

1/ Includes drainage upstream from report area.

chance of exceedance in any year), are obtainable by multiplying the median annual peak discharge by the appropriate ratio for any selected recurrence interval determined from figure 20.

It must be emphasized that the curves in figures 19 and 20 apply only to unregulated streams draining rural areas. Flood discharges in urban areas are significantly higher owing to the presence of pavement and storm sewers, which shorten the concentration time of the runoff.

The term "recurrence interval", as commonly used in comparing the severity of floods, is based upon a continuous series of annual flood events. The reciprocal of the recurrence interval is the probability, or the percentage chance, of a flood of a given magnitude or greater occurring within any one year. In the design of structures such as bridges or culverts, it is necessary to consider the probability that a flood-peak discharge with a selected recurrence interval will be exceeded within the design lifetime of the structure. Table 13 presents this relationship and is based upon the binomial distribution $P = 1-(1-p)^n$, where P is the probability that a 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 in detail by Markowitz (1971).

HURRICANE TIDES

Hurricanes, or tropical cyclonic storms, have struck Connecticut frequently in the past. The first New England hurricane recorded was that of August 15, 1635, and the greatest in the 20th century to date crossed the area on September 21, 1938. This storm caused abnormally high tides and produced flood heights about 10 feet above mean sea level along the shore. Two major hurricanes, "Carol" and "Edna," hit the area only 11 days apart, on August 31 and September 11, 1954, causing loss of life and extensive property damage.

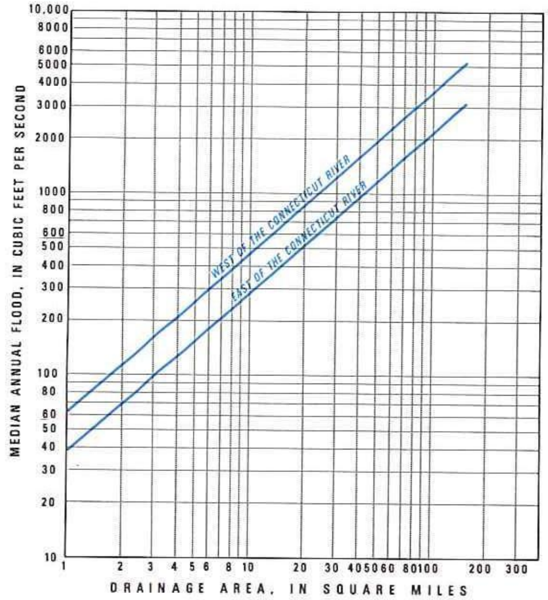


Figure 19.--Relation between median annual flood and drainage area

Table 12.--Magnitude and recurrence intervals of maximum annual flood-peak discharges for period of record at long-term stream-gaging stations.

(Computed by the log-Pearson type III method.)

Station No. (pl. A)	Stream and place of measurement	Period of record (water years)	Drainage area (mi^2)	Flood discharge, in cubic feet per second, for indicated recurrence interval, in years: 2	5	10	25	50	100
0119300	Connecticut River near Middletown	1947-71	10,882 1/	94,000	130,000	150,000	180,000	200,000	220,000
01193500	Salmon River near East Hampton	1929-71	102	2,500	4,000	5,600	7,800	9,800	12,000
01193800	Hemlock Valley Brook at Hadlyme	1961-71	2.62	120	195	260	350	440	530
01194000	Eightmile River at North Plain	1940-71	20.1	700	1,050	1,450	1,950	2,400	2,900
01194500	East Branch Eightmile River near North Lyme	1938-71	22.3	620	970	1,250	1,700	2,100	2,500
01195000	Menunketesuck River near Clinton	1942-67	11.2	425	650	890	1,200	1,500	1,850

1/ Includes drainage upstream from study area.

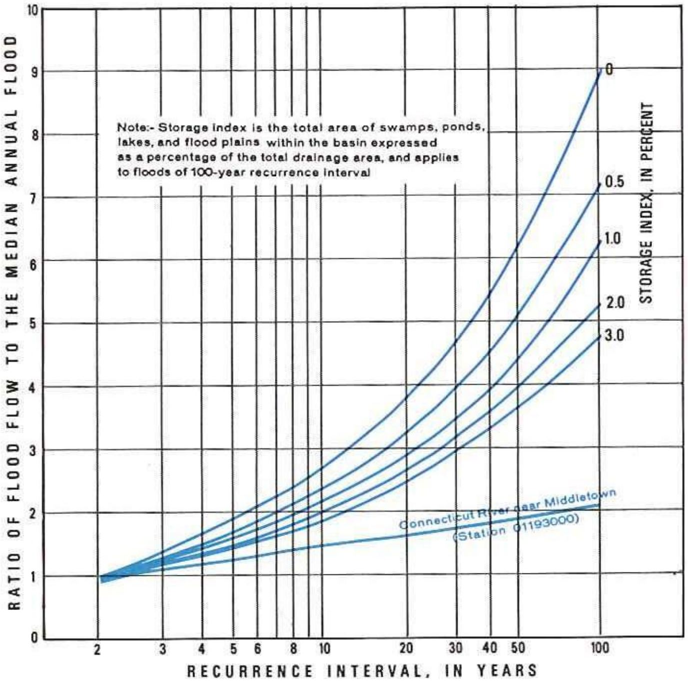


Figure 20.--Recurrence intervals of peak flows

Table 13.--Probability that the recurrence of annual flood discharges will be exceeded in the design lifetime

(Example shows that there is a 72-percent chance of a flood peak with a 20-year recurrence interval to be equaled or exceeded within a 25-year period)

Recurrence interval of annual flood peak (years)	Probability (percent chance) that an annual flood peak or high mean discharge with a selected annual recurrence interval will be equaled or exceeded within the indicated design lifetime, in years				
	1	10	25	50	100 (years)
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 14.--Frequency of maximum annual tides

Height of tide at New Haven (feet above mean sea level)1/	Height of tide at New London (feet above mean sea level)1/	Recurrence interval (years)
7.4	4.6	2
8.0	5.8	5
8.6	6.7	10
9.3	7.7	20
10.4	9.2	50
11.4	10.5	100
12.6	11.8	200

1/ National Geodetic Vertical Datum of 1929.

The table shows that the hurricane tide height on September 21, 1938, estimated at 10 feet above mean sea level at New Haven and recorded at 9.7 feet at New London, had a recurrence interval of about 50 and 75 years at the respective sites.

The U.S. Army Corps of Engineers (1973) developed frequency relationships of maximum annual tides at New London and New Haven, based on 34 years of record; the results are summarized in table 14.

GROUND WATER

An unseen but important part of the hydrologic cycle occurs beneath the land surface as ground water, moving through the saturated zone from areas of recharge to areas of discharge. The earth materials in the saturated zone --including both unconsolidated deposits and bedrock-- constitute the hydrogeologic framework for ground-water storage and circulation. Optimum water-resources development and management require information on the extent and hydrologic characteristics of these materials, on the amounts of water available, and on the ground-water flow system and its relation to the total hydrologic cycle.

Ground water has several advantages over surface water as a source of supply. Usually treatment is not needed to meet drinking-water standards, and the public water-service areas are commonly situated in valleys that are underlain by the largest sources of ground water. Delivery costs, therefore, are less. Another advantage is that little land is used for a well site, and most of the surrounding area is available for other compatible uses. Furthermore, in upland areas, where ground water is more limited in quantity, it is widely available and is a suitable source for individual homes.

HYDROLOGIC FRAMEWORK

The earth materials that are capable of yielding usable quantities of ground water to wells are termed aquifers. Aquifers are composed of both unconsolidated deposits and bedrock. The unconsolidated deposits include stratified drift and till, while the bedrock is composed of either sedimentary, igneous, or metamorphic rocks. The characteristics of these aquifers are summarized in table 15, and the areal distribution and subsurface relationship between these water-bearing units are shown on plates B and C.

Stratified drift, an unconsolidated water-sorted sediment, is composed of interbedded layers of gravel, sand, silt, and clay. These materials were deposited during the deglaciation of the basin (Flint, 1930) and are generally restricted to the valley areas that served as drainageways for glacial melt water or were sites of temporary glacial lakes. The stratified drift generally fills the valley bottoms below the present streams but also may form terraces along the valley sides.

Till, locally called "hardpan", is an unconsolidated, nonstratified, heterogeneous sediment deposited directly by glacial ice. Most of the bedrock in the basin is overlain by till that is less than 30 feet thick, although locally, it may exceed 100 feet in thickness.

Bedrock aquifers include sedimentary, igneous, and metamorphic units. Sedimentary bedrock consisting of interbedded sandstone, shale, and conglomerate underlies the western and northwestern parts of feet thick in the central Connecticut lowland and probably exceed 11,000 feet within the basin (Krynine, 1950; Lehmann, 1959). This thick

Table 15.--Principal water-bearing units in the study area

Water-bearing unit	Thickness	General character	Water-yielding properties
Stream deposits	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	Less than 1 foot to to about 300 feet	Interbedded layers of well-sorted gravel, sand, silt, and clay. Underlies 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	Generally less than 10 feet but ranges from less than 1 foot to about 150 feet	Non-stratified 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	Less than 1 foot to more than 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 supplies. Water occurs in bedding planes, fractures, and intergranular pore spaces.
Igneous bedrock	Less than 1 foot to about 800 feet	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	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.

sequence of sedimentary rocks is not continuous; it is divided into four distinct units by three lava flows composed of basalt (igneous rock locally termed "traprock"). The sedimentary units and interbedded igneous rocks are shown on plate C.

Much older bedrock underlies the remainder of the basin and also extends beneath the sedimentary rocks. These rocks, termed crystalline bedrock in this report, are equivalent to the metamorphic rocks in the adjacent Quinnipiac River basin (Mazzaferro and others, 1979). Crystalline bedrock includes a variety of metamorphic and igneous rock types such as gneiss, schist, and pegmatite. Many of these rock types are the products of metamorphism - a process whereby sedimentary and igneous rocks are altered in composition and fabric by high temperature and pressure.

STORAGE AND CIRCULATION

The framework for the storage and circulation of ground water, as previously mentioned, consists of the principal aquifers--stratified drift, till, and bedrock--as well as streambed deposits that underlie major streams. Each type of aquifer has characteristic properties that significantly affect the storage and movement of water and determines their usefulness as sources of supply. Streambed deposits are the medium that connects the subsurface aquifers to surface-water bodies. As such, they often determine the degree to which ground-water supplies may be augmented by induced recharge (See discussion on p. 37-39).

Stratified drift and till contain open spaces or pores between individual grains, whereas the bedrock contains open spaces along cracks or fractures. Below the water table, which is the upper surface of the saturated zone, the pores and fractures are completely filled with water. Stratified drift and till have a greater proportion of open spaces than fractured bedrock, and consequently, where saturated, contain significantly more water per unit volume. The greatest quantities of ground water, therefore, underlie the areas that have the thickest saturated deposits of stratified drift and till, but the availability is dependent on factors other than the amount in storage.

Ground water occurs in aquifers within the basin under both unconfined and confined conditions. In most places, water only partly fills the aquifer and the upper surface of the saturated zone is free to rise and fall. In a few places, ground water completely fills an aquifer that is overlain by a relatively impermeable confining layer. The upper surface of the saturated zone is the top of the aquifer and is not free to move. Ground water under such conditions is said to be confined or under artesian conditions.

The extent of ground-water flow systems, in respect to both areal size and depth of circulation, is a function of the location and type of hydraulic boundaries. Hydraulic boundaries in turn are controlled by a number of factors such as rate and amount of recharge, the depth of fracturing in the bedrock, and topography and geology. The direction and rate of ground-water movement are governed by the distribution and hydraulic characteristics of the subsurface units and by the pressure (head) differences in the saturated zone.

Circulation of ground water is usually confined within each basin drained by a perennial stream system. The saturated zone within such major flow systems may be thought of as a large underground reservoir, the top and bottom boundaries of which are the water table and nonfractured bedrock, respectively. Previous studies (Gregory, 1909; Ellis, 1909) indicate that 300 to 400 feet below the bedrock surface, water-bearing openings are few and small and the rocks can be considered relatively impermeable. The vertical-flow boundaries are generally located beneath the surface-water drainage divides of each basin. In coastal areas, the subsurface boundary of the flow system adjacent to the ocean is inferred to be the contact zone between fresh and salty ground water (termed the "zone of diffusion").

Large scale or "regional" flow systems may also extend across the major drainage divides that separate the lower Connecticut River basin from adjacent basins. Some evidence exists of regional flow into the basin along the western margin beneath the towns of Durham, Middlefield, Middletown, and Berlin. In this area, sedimentary bedrock is exposed west of the basin drainage divide but dips eastward beneath the basin as shown in the cross section on plate C. Semi-confining units composed of basalt and shale retard vertical migration of water and direct the flow eastward along more permeable bedding planes. However, the amount of ground water moving in this large regional flow system is unknown but believed to be very small. Present data is insufficient to determine the extent or magnitude of such large-scale flow systems and consequently, they are not discussed further in this report.

Minor flow systems, either temporary or permanent, may exist within the major systems of ground-water circulation. In fact, several minor flow systems may be incorporated within a major one. Major and minor flow systems and the general pattern of circulation from areas of inflow (recharge) to areas of outflow (discharge) are depicted in figure 21.

Ground water in the basin, if not evaporated, transpired, or withdrawn by wells, eventually discharges to lakes, streams, or Long Island Sound. The transit time of ground water in the saturated zone varies considerably, depending on where recharge and discharge occur and the hydrologic characteristics of the aquifer. Generally, the closer to the basin drainage boundary that the water enters the saturated zone, the deeper and greater the distance traveled before it is discharged. Some ground water will therefore be in contact with rock or soil materials for considerably longer periods of time, consequently affecting its chemical quality. In minor flow systems, water usually is not in circulation long enough to significantly affect its quality.

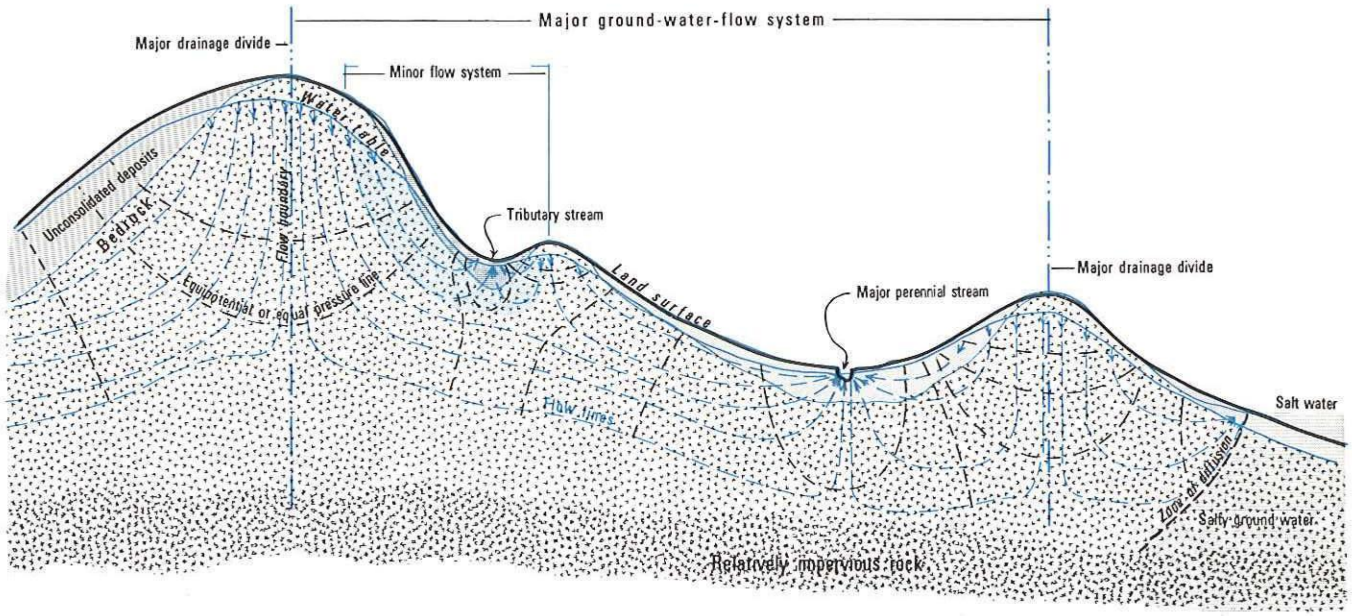


Figure 21.--Idealized cross section showing flow lines and boundaries of a ground-water-flow system

Because the study area is bordered on the south by Long Island Sound, there are many minor flow systems located between the mouths of perennial streams that discharge ground water directly into the Sound. These systems have boundaries between fresh and salty ground water that fluctuate, depending upon the quantity of ground-water discharge and the tide level. The contact between fresh and salty ground water is not a sharp line but rather a brackish zone of diffusion. In coastal or estuarine areas where this fresh-salt-water boundary extends under the shoreline, wells may draw in the saline water.

A quantitative expression of the ground-water circulation in a flow system under natural conditions is given in the following equation (after Schicht and Walton, 1961):

$$G_{wr} = (G_{wro} + G_{wet} + U) \pm S \quad ,$$

where G_{wr} = ground-water recharge or inflow ,

G_{wro} = ground-water runoff ,

G_{wet} = ground-water evapotranspiration ,

U = underflow , and

S = change in ground-water storage .

All the variables in the above equation may differ in magnitude, with time and areally from one part of a basin to another. This diversity is due to a number of hydrologic, geologic, climatologic, ecologic, cultural, and topographic factors. Ground-water recharge is derived principally from precipitation and occurs mainly during the non-growing season (roughly from October through April), when precipitation exceeds evapotranspiration. Ground-water discharge consists mainly of runoff to streams and evapotranspiration and occurs throughout the year. Ground-water evapotranspiration occurs mainly during the growing season. The hydrograph of figure 22, for observation well MT 261, shows typical seasonal water-level changes that accompany changes in rates of ground-water recharge and discharge.

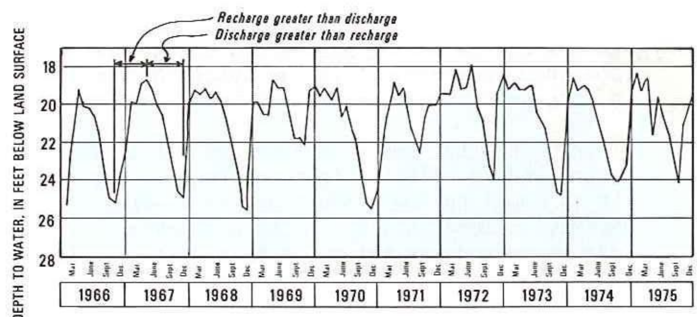


Figure 22.--Water-level fluctuations in observation well MT 261, 1966-75

AQUIFER CHARACTERISTICS

Stratified drift and till, together with the sedimentary, igneous and metamorphic (crystalline) bedrock, are the major aquifers in the study area. These units, however, differ from one another in their ability to store and transmit water. Saturated stratified drift, particularly where composed of sand and gravel, is the only aquifer capable of supplying large quantities of ground water on a sustained basis. Wells tapping the bedrock aquifers generally have yields adequate for domestic and some commercial uses. Till is an inadequate source for most domestic requirements and is seldom tapped by new wells.

The ability of the stratified drift and till aquifers to yield water and the response to pumping may be determined by use of appropriate flow equtions if the hydraulic properties and boundaries are known. Bedrock aquifers, because of the complex fracture systems, have variable hydraulic properties, and cannot be as readily analyzed mathematically.

The hydraulic properties of stratified drift and till, that control their ability to yield water, are the storage coefficient and transmissivity. Transmissivity is the product of two other properties, average hydraulic conductivity and saturated thickness. These terms are defined in the glossary while the symbols and units of measurements used for these aquifer properties are as follows:

1. Storage coefficient is designated by the symbol S and is a dimensionless ratio expressed as a decimal fraction. Throughout the basin, the stratified drift and till aquifers are generally unconfined and the storage coefficient is equal to the specific yield S_y, which is the volume of water draining by gravity from a unit volume of aquifer, expressed as a percentage of the unit volume.

2. Hydraulic conductivity is designated by the symbol K and is expressed in units of feet per day. The hydraulic conductivity may vary with the direction of flow, particularly in stratified drift, and symbols K_v and K_h may be used for the hydraulic conductivity in the vertical and horizontal directions, respectively. Where the symbol K appears without a subscript, conductivity in the horizontal direction is assumed.

3. Saturated thickness, designated by the symbol b, is expressed in feet. For unconfined aquifers it is measured from the water table to the bottom of the aquifer, whereas, for confined aquifers, it is the total thickness of the unit.

4. Transmissivity, designated by the symbol T, is expressed in units of feet squared per day. It is equal to the product of the average hydraulic conductivity in the horizontal direction and the saturated thickness ($T = K_h x b$).

Prior to development by wells, an aquifer is in a state of equilibrium, in that ground-water recharge equals discharge over a long period of time. Discharge from wells upsets this balance by taking water out of storage. To attain a new state of equilibrium requires that all pumping be balanced by:

1. an increase in recharge, or
2. a decrease in discharge, or
3. a combination of 1 and 2.

STRATIFIED DRIFT

Widely distributed stratified drift covers only about 19 percent of the area (plate B). The major occurrences are in the Mattabesset, Coginchaug, Connecticut, and Eight Mile River valleys and in the coastal lowlands.

Stratified drift may be overlain by younger unconsolidated materials in a few places. For the purposes of this report, these younger, postglacial deposits are considered part of the underlying stratified drift. These deposits, that include alluvium, loess, artificial fill, peat and swamp muck, are generally thin and limited in extent. Flint (1971, 1975) mapped the surficial geology in four coastal quadrangles and interpreted some hummocky, elongate, boulder-mantled ridges as end moraines. These ridges are also included as underlain by the stratified drift on plate B because the materials are water-sorted at most sites and the hydraulic characteristics and infiltration rates are higher than in till and probably as high as in some fine-grained stratified-drift deposits.

Stratified drift, in the report area, has been separated into five units, based on the dominant grain size in the saturated zone. These categories, also shown on plate B, include (1) coarse-grained material composed predominantly of sand and gravel with particles larger than 0.125 millimeters (mm) in diameter; (2) fine-grained material composed predominantly of sand, silt, and clay, with particles smaller than 0.125 mm in diameter (includes lake-bed deposits that yield little or no water to wells); (3) fine-grained deposits overlying coarse-grained deposits, and (4) undifferentiated material where no grain-size information is available.

The coarse-grained deposits in the valleys of East Branch Eightmile, Eightmile, and Connecticut Rivers constitute some of the most important aquifers in the basin; most of which are shown on plates B and D. Areas underlain by the fine-grained stratified-drift deposits include most of the low terraces along the Connecticut River at the towns of Portland, Haddam, and East Haddam, the coastal segments of Guilford, and small parts of Colchester and Old Lyme. The principle areas of silt and clay are in the valleys of the Mattabesset and Coginchaug River, and Sumner Brook.

Saturated, coarse-grained stratified-drift deposits that are not physically and hydraulically connected are considered as separate aquifers in this report. The quantity of water that can be withdrawn on a temporary or sustained basis from such aquifers depends upon (1) their hydraulic properties, (2) the location and type of hydraulic boundaries, (3) the quantity and variability of natural recharge and discharge, (4) the quantity of water that can be induced to infiltrate from adjacent streams and lakes, and (5) proximity to the saltwater-freshwater interface in coastal areas.

Hydraulic Properties

The saturated thickness of stratified drift is an important characteristic in determining aquifer and well yields. Where all other conditions are equal, a thick aquifer will produce more than a thin one because of its larger available drawdown. The saturated thicknesses shown on plate B, however, are not always a reliable index of the head available for development because of variable grain-size distribution that may prevent successful completion of a well in the lower part of the section. Storage coefficient and transmissivity are the properties that govern the ability of a stratified-drift aquifer to store and transmit water; these are shown diagrammatically in figure 23. The maximum reported total thickness of stratified drift is 200 feet at well P105 in Portland;

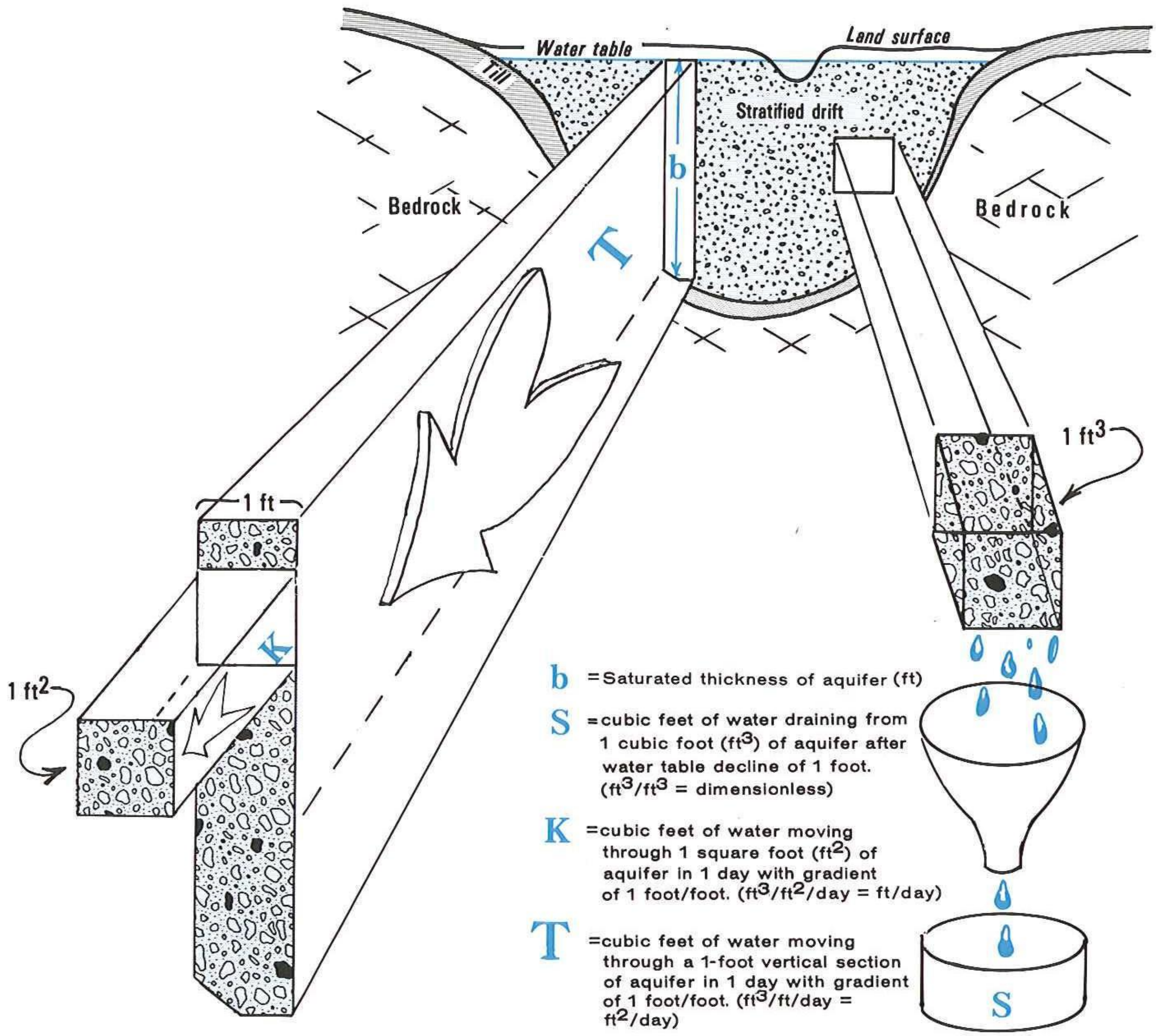


Figure 23.--Hydraulic and geometric characteristics of a stratified-drift aquifer

the saturated thickness is 160 feet. Stratified-drift deposits with saturated thicknesses in excess of 100 feet underlie several other towns, such as Berlin, Cromwell, Haddam, and Old Saybrook. The median saturated thickness computed from records of 81 wells is 51 feet, according to information contained in a well-data report by Bingham and others (1975).

Saturated thickness of stratified drift, shown on plate B, is determined largely from drillers' logs of wells and test borings. In many logs, however, it is difficult to distinguish stratified drift from underlying till, and thus in some locations, the entire saturated section above the bedrock may be represented as stratified drift. At most sites, however, till is thin (5 feet or less) or absent, and the contours closely approximate the saturated thickness of the stratified--drift aquifers.

The thickness of the aquifer is influenced by the configuration of the underlying bedrock. Commonly, bedrock is deeper at the center of a valley than at the sides, and therefore saturated thickness is generally at a maximum near the valley axis. The greatest thickness seldom coincides with the present course of the major stream, which tends to meander over the valley surface.

Storage coefficient, together with transmissivity, can be used to estimate the water-table drawdown due to pumping wells, for any given time period. The amount of water that can be withdrawn from an unconfined aquifer is only a fraction of the total in storage and is derived from gravity drainage. The storage coefficient represents the amount of water that would drain from a unit volume of aquifer and depends on the aquifer's grain-size distribution and the period of time it is allowed to drain (Prill and others, 1965; Johnson, 1967). The storage coefficient of stratified-drift aquifers commonly ranges from 0.05 to 0.30, depending on the grain size of the material and time period. In the study area, a value of 0.20 is assumed to be a reasonable and probably conservative value of storage coefficient applicable to long time periods (100 to 200 days).

Transmissivity values calculated for stratified drift at 168 sites are listed in tables 16 and 17. Most of these calculations are derived from specific-capacity data or from drillers' logs, many of which include grain-size analysis. Most values generally are between 500 and 25,000 feet squared per day (ft^2/d), but the maximum value is 68,000 ft^2/d at well MT 288. (See plate A for locations.)

The most reliable values are the 30,700 ft^2/d and 40,100 ft^2/d, obtained from analysis of pump-test data for wells MT 287 and MT 288, respectively (table 16; Baker, 1966, table 1). In both tests, the wells discharged at constant rates of 1,575 gal/min for 30 hours and periodic water-level measurements were made in an adjacent network of observation wells. Similar tests also were made at wells MT 389 and 390. Transmissivity values of 10,700 ft^2/d were determined from the test data (Geraghty and Miller, 1964), using the Theis nonequilibrium method of analysis (Theis, 1935, Ferris and others, 1962).

Specific capacity, the yield per foot of drawdown of a well, also may be used to estimate aquifer transmissivity (Theis, 1963). Yield and drawdown data from 74 screened wells were used in calculating transmissivity of the stratified drift in the study area (table 16). The data are generally based on drillers' records and are subject to errors inherent in conducting tests and reporting the results under nonstandardized conditions. Estimates of transmissivity based on specific capacity data are generally conservative, but nevertheless useful. In table 16, drawdown data has generally been adjusted for the affects of partial penetration, but is not corrected for a number of other factors, such as aquifer dewatering and well efficiency. This results in estimates that are probably lower than the actual values. In cases where the wells are near streams or ponds that constitute line-source (recharge) boundaries, however, the estimated values may be higher than the actual.

Logs of wells and test holes can also be used to estimate transmissivity. The hydraulic conductivity of unconsolidated sediments such as stratified drift is directly related to grain-size characteristics (Krumbein and Monk, 1942; Masch and Denny, 1966). A relationship between the median grain size and sorting (as expressed by the uniformity coefficient) of stratified drift and laboratory-determined values of hydraulic conductivity in the horizontal direction has been developed in previous Connecticut studies (Randall and others, 1966; Thomas, M. P., and others, 1967; Thomas, C. E., and others, 1968; Ryder and others, 1970). This relationship, modified in respect to sorting index, is shown graphically in figure 24. In the study area, transmissivity calculations were made for 94 test holes (table 17) on the basis of this relationship.

An example of the manner in which the values are estimated from logs is given in table 18. A value of hydraulic conductivity is assigned to each lithologic unit on the basis of grain size and sorting information. In most cases, the graph in figure 24 is utilized. For logs where the descriptive terms did not allow a reliable estimate of grain-size characteristics, a catalog of drillers' terms and corresponding approximate hydraulic conductivities was developed. The approximate values assigned are summarized in table 19.

Transmissivity estimates based on logs are contained in tables 16 and 17. This method is the most subjective of the three used and generally the least accurate. In many cases, however, agreement is good between the estimates derived from descriptive logs and more quantitative techniques. Of the 47 wells in table 16 that have values from logs and from specific capacity, about one-third are comparable; that is, the values are generally considered more accurate, estimates from logs are internally consistent, particularly if accompanied by grain-size data, and they provide the largest source of information on the transmissivity of stratified drift in the basin.

Table 16.--Calculated transmissivity of stratified drift at selected well sites

(Well locations on plate A and transmissivities on plate B. Additional well data listed in basic-data report, (Bingham and others, 1975)

Local well no.	Well diameter (in)	Screen length (ft)	Percent of aquifer screened	Pumping rate (gal/min)	Duration of test (hrs)	Drawdown Reported (ft)	Drawdown Adjusted (ft)1/	Specific capacity From reported drawdown gal/min/ft	Specific capacity From adjusted drawdown gal/min/ft	Transmissivity (ft^2/d) From well logs2/	Transmissivity From unadj. spec. cap.3/	Transmissivity From adj. spec. cap.4/	Transmissivity From pumping test
Town of Berlin													
B 373	10	8	21	200	24	16	7.8	12.5	25.6	5,000		5,000	
B 384	8	8	17	190	45	21	8.6	9.0	22.1	2,300		4,500	
B 385	12	10	21	610	48	11	4.8	55.4	127.1	4,050		26,000	
B 386	12	8	15	350	44	29	12.3	12.1	28.5	8,400		5,600	
B 387	12	8	24	160	3	6	2.9	26.7	55.2	7,200		9,400	
B 388				50		14		3.6			900		
B 389				37		18		2.1			500		
B 393	8	10	22	240	24	14	5.4	17.1	44.4	25,000		9,000	
B 400	8	2	7	150	24	13	5.8	11.5	25.9	1,350		5,000	
Town of Chester													
CH 253	6	4	11	25	8	25	9.6	1.0	2.6			350	
CH 268				63		58		1.1			300		
Town of Clinton													
CL 190	12	20	26	1,000	91	44	22.6	22.7	44.2	33,000		10,000	
CL 191	12	18	19	890	118	38	13.8	23.4	64.5	10,600		14,700	
CL 199	8	18	22	575	24	34	11.3	16.9	50.9	5,000		10,700	
CL 217	8	10	13	50	20	67	23.0	0.8	2.2	10,000		300	
Town of Colchester													
CO 266	12	10	20	200	24	6	2.6	33.3	76.9	16,000		18,800	
CO 316	16	10	15	185	50	55	23.6	3.4	7.8	2,600		1,300	
CO 325				50		4		12.5			3,300		
Town of Cromwell													
CR 264				25		75		.3			100		
CR 314				18		50		.4			100		
Town of East Hampton													
EHM 369				12		15		.8			200		
Town of Essex													
ES 90	8	5	24	100	24	7	6	14.3	17	12,900		3,200	
ES 91	8	8	16	25	8	36	13.9	.7	1.8	13,000		250	
ES 92	18	10	22	250	79	33	16.5	7.6	15.2	23,900		3,800	
ES 100	8	10	12	160	24	64	22.2	2.5	7.2	11,000		1,200	
ES 114				30		25		1.2			300		
ES 116	8	8	17	160	23	23	9.0	7.8	20.0	10,000		3,900	
ES 117	12	17	42	400	28	28	18.2	14.3	22.0	6,400		4,200	
Town of Guilford													
G 374	12	20	24	800	26	26	9.8	30.8	81.6		23,000	17,400	
G 389	10	10	40	100	24	10	7.4	10.0	13.5	800		2,500	
G 401	8	7	15	50	24	35	13.8	1.4	3.6	4,000		500	
Town of Haddam													
HD 414	10	11	10	40	4	92	30.5	.43	1.3	660		150	
HD 415	10	11	22	300	54	30	12.3	10.0	24.4	17,700		5,200	
HD 416	10	10	24	300	30	16	6.9	18.8	43.5	13,000		9,100	
HD 439				25		34		.7			200		
Town of Killingworth													
K 170				50		4		12.5			3,300		
Town of Lyme													
L 227	6	5	7	45	26	26	3	1.7	15	15,900		2,700	
L 228	6	10	34	12	18	18	9.9	.7	1.2	1,100		150	
L 232				25		38		.7			200		
L 233				10		20		.5			100		
L 235	2	10	25	26	–	11	5.5	2.4	4.7	6,000		500	
Town of Madison													
MA 287	6	2	2	2	2	70	2	.03	1	4,300		100	
MA 307				78		62		1.3			350		
MA 308				25		61		.4			100		
MA 309				55		59		.9			240		
City of Middletown													
MT 235	8	10	23	310	118	21	8.4	14.8	36.9	–		8,000	
MT 239	8	10	19	328	7	26	9.9	12.6	33.1	5,800		5,800	
MT 256	8	6	11	12	–	45	16.9	.3	.7	620		50	
MT 258	8	10	20	411	24	12	4.6	34.2	89.3			17,400	
MT 260	8	10	16	400	24	15	5.5	26.7	72.7	11,300		14,700	
MT 287	12	20	26	1,570	30	16	6.1	98.1	257.4	7,800		63,000	30,700 5/
MT 288	12	20	25	1,570	30	13	4.9	120.8	320.4	17,000		68,000	40,100 5/
MT 300				50		30		1.7			450		
MT 308	8	10	16	97	48	9	3.3	10.8	29.4	27,000		5,400	
MT 309	8	15	29	100	48	18	6.9	5.6	14.5	21,000		2,700	
MT 321	12	20	38	1,000	48	22	12.2	45.4	82.0	19,000		18,800	
MT 324	10	12	27	520	24	6	3.3	86.7	157.6	3,000		20,000	
MT 325				33		20		1.6			400		
MT 326				50		8		6.2			1,600		
MT 348	18	20	29	1,250	72	15	8.6	83.3	145.3	33,000		40,000	
MT 386	18	15	35	700	24	14	9.1	50.0	76.9	5,800		16,000	
MT 387	18	15	31	1,530	22	28	17.4	54.6	87.9	7,400		17,000	
MT 389	18	10	24	757	3	14	7.3	54.1	103.7	9,000		18,800	10,700 6/
MT 390	18	10	21	925	3	18	9.4	51.4	98.4	13,000		16,000	10,700 6/
MT 392	8	10	16	200	24	56	20.7	3.6	9.7	4,500		1,300	
Town of Old Lyme													
OL 88				20		105		.2			50		
Town of Old Saybrook													
OS 259	10	10	21	150	48	33	13.5	4.6	11.1	7,200		1,900	
OS 261	8	8	35	40	625	12	7.8	3.3	5.1	12,000		700	
OS 262				5		7		.7			200		
Town of Portland													
P 106	12	13	18	299	-	35	13.6	8.5	22.0	6,200		2,700	
Town of Westbrook													
WE 257	12	18	45	360	96	28	22.4	12.9	16.1			3,100	
WE 268				50		7		7.1			1,900		
WE 269	8	20	24	245	386	58	20.3	4.2	12.1	16,000		2,700	
WE 270				400		34		11.8			3,200		

1/ Reported drawdowns corrected for the affects of partial penetration using method described by Walton (1962, p. 8, table 2). Assumed ratio of vertical to horizontal hydraulic conductivity is 0.01.

2/ Method outlined in this report on p. 42.

3/ Computed using approximate expression T = (Specific capacity) (2000/7.5) (Mazzaferro and others, 1979.)

4/ Determined from Walton (1967, p. 13, fig. 5-7).

5/ Reported by Baker and others (1965, p. 29) using Theis nonequilibrium formula.

6/ Reported by Geraghty and Miller (1964, p. 62-63).

Table 17.--Transmissivity of stratified drift calculated from grain-size data or driller's logs of test holes

[Test hole locations on plate A and transmissivities on plate B; logs and additional data listed in basic data report (Bingham and others, 1975)]

Local test hole no.	Depth (ft below lsd)	Water level (ft below lsd)	Saturated thickness (ft)	Transmissivity (ft^2/d)
Town of Berlin				
B 1 th	59	4	49	2900
B 41 th	103	25	70	4800
B 50 th	75	9	66	1000
B 62 th	42	0	42	2100
B 80 th	102	1	101	5500
B 83 th	61	2	59	2300
Town of Chester				
CH 13 th	38	0	27	600
Town of Clinton				
CL 18 th	134	3	131	8600
CL 30 th	67	3	64	3350
CL 50 th	67	3	64	12,800
CL 62 th	44	3	37	1200
Town of Colchester				
CO 63 th	62	3	54	250
CO 75 th	75	5	70	1100
CO 86 th	68	3	65	1000
CO 87 th	66	20	29	400
CO 88 th	73	30	43	3600
CO 93 th	63	8	55	4100
Town of Deep River				
DR 17 th	54	4	50	600
DR 19 th	36	4	27	5900
DR 26 th	63	3	60	2400
Town of Durham				
D 6 th	45	5	40	1300
Town of East Haddam				
EHD 1 th	53	0	37	1100
EHD 5 th	109	11	80	1900
EHD 9 th	49	4	42	8000
Town of East Hampton				
EHM 17 th	56	5	48	4600
Town of Essex				
ES 12 th	45	2	37	2000
ES 22 th	109	3	106	2500
ES 23 th	42	10	32	2800
ES 35 th	44	3	37	700
ES 37 th	61	0	58	500
ES 44 th	86	5	85	1800
ES 49 th	45	4	41	4400
ES 57 th	40	2	38	4000
Town of Guilford				
G 26 th	46	12	34	1300
G 41 th	39	1	38	2100
G 69 th	35	4	26	2200
Town of Haddam				
HD 19 th	112	8	104	20,000
HD 20 th	67	4	58	35,000
HD 21 th	111	5	103	4000
HD 22 th	102	10	87	1500
HD 23 th	112	5	100	12,500
Town of Hebron				
HB 4 th	78	5	38	10,000
Town of Killingworth				
K 2 th	30	4	26	3300
K 8 th	86	3	83	5100
K 10 th	85	3	82	3200
Town of Lyme				
L 1 th	104	32	72	7300
L 2 th	112	16	96	5300
Town of Madison				
MA 29 th	32	4	20	1900
MA 33 th	30	9	21	800
MA 35 th	45	8	25	500
MA 37 th	27	3	24	1200
MA 43 th	43	1	39	1600
Town of Marlborough				
MB 3 th	26	4	16	1100
MB 11 th	50	11	39	2700
MB 13 th	28	12	16	2900
MB 27 th	64	21	32	200
City of Middletown				
MT 34 th	81	28	53	1000
MT 116 th	85	15	61	1900
MT 121 th	54	2	32	800
MT 132 th	65	8	57	2000
MT 133 th	74	10	65	2200
Town of Old Lyme				
OL 32 th	94	15	79	900
OL 34 th	68	20	48	2400
OL 36 th	64	10	46	2000
OL 39 th	46	8	25	7000
OL 40 th	52	11	34	5500
OL 41 th	55	5	46	2800
OL 45 th	71	0	71	300
Town of Old Saybrook				
OS 20 th	62	21	40	700
OS 24 th	27	6	13	1000
OS 29 th	40	4	36	1200
OS 34 th	76	4	72	800
OS 43 th	42	5	37	1600
OS 48 th	75	18	55	2400
OS 49 th	29	1	11	900
OS 51 th	30	3	27	1000
OS 60 th	40	15	25	2100
Town of Portland				
P 1 th	57	0	57	1600
P 6 th	97	20	93	1200
P 19 th	118	35	83	1700
P 20 th	72	41	12	250
P 23 th	167	12	117	800
P 28 th	81	2	78	1300
Town of Salem				
SM 2 th	38	5	27	300
SM 3 th	53	7	46	2200
SM 4 th	47	5	37	3500
SM 10 th	36	4	32	1700
SM 14 th	47	4	36	1300
Town of Westbrook				
WE 12 th	32	4	23	1400
WE 31 th	62	5	57	4300
WE 34 th	108	1	107	5800
WE 46 th	25	5	20	1200
WE 50 th	14	5	9	1800
WE 55 th	40	2	34	2000

Table 18.--Estimating transmissivity of stratified drift from logs

(Example shown is test hole HD 20th, drilled by U.S. Geological Survey in 1972. Depth to water, 4 feet below land surface.)

Material description	Depth (ft below lsd) From	To	Saturated thickness, (ft)	Assigned hydraulic conductivity, (ft/d)	Transmissivity of log interval (ft^2/d)
Loam, black	0	1	0		
Gravel, dirty	1	5	1	100	100
Sand, very fine to medium; some coarse to very coarse sand; trace of silt; scattered gravel	5	7	2	100	200
Sand, fine to very coarse; trace very fine sand; trace silt; trace very fine gravel	7	30	23	800	18,400
Sand, coarse to very coarse, and very fine to fine gravel	30	41	11	1,500	16,500
Sand, very fine to medium; little coarse to very coarse sand; trace to some silt; occasional red and gray silt and clay varves	41	61	20	20	400
Cobbles and gravel	61	62	1	100	100
Sand, very fine to very coarse, gray (till?)	62	66			
TOTAL			58		35,700

Table 19.--Hydraulic-conductivity values assigned to drillers' terms for stratified-drift units.

Drillers' term	Hydraulic conductivity (ft/d)
Gravel, clean	800
Gravel	270
Gravel, dirty	80
Sand, clean, and gravel	400
Sand and gravel	200
Sand, medium to coarse	200
Sand, fine, some gravel	80
Sand, coarse	400
Sand, medium	100
Sand, fine to coarse	50
Sand, fine	30
Sand, very fine	9
Sand, dirty	50
Sand, fine, silty	13
Sand, fine, and clay	4
Silt and clay	0.3

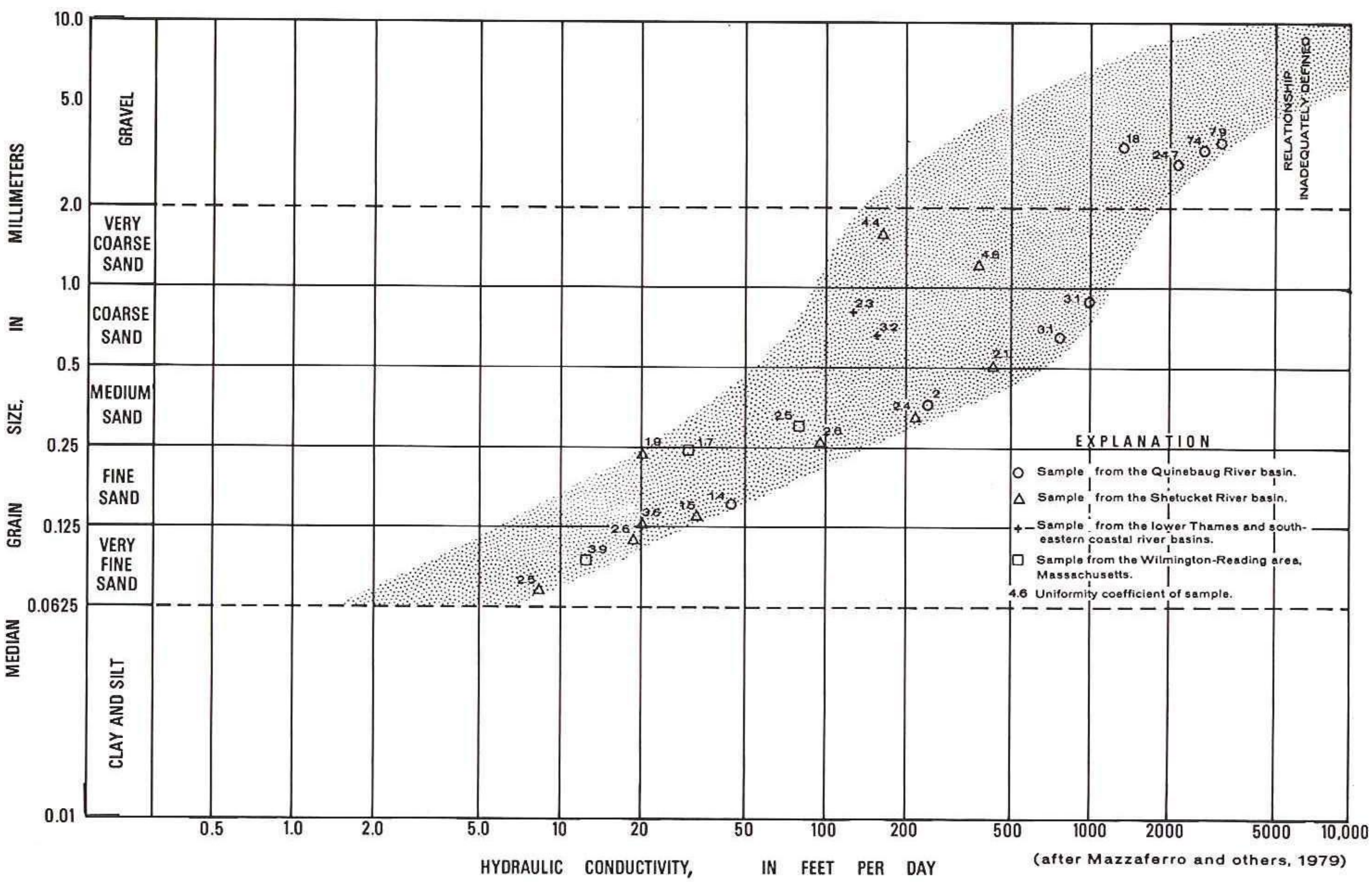


Figure 24.--Hydraulic conductivity of stratified drift in southern New England as a function of median grain size and sorting

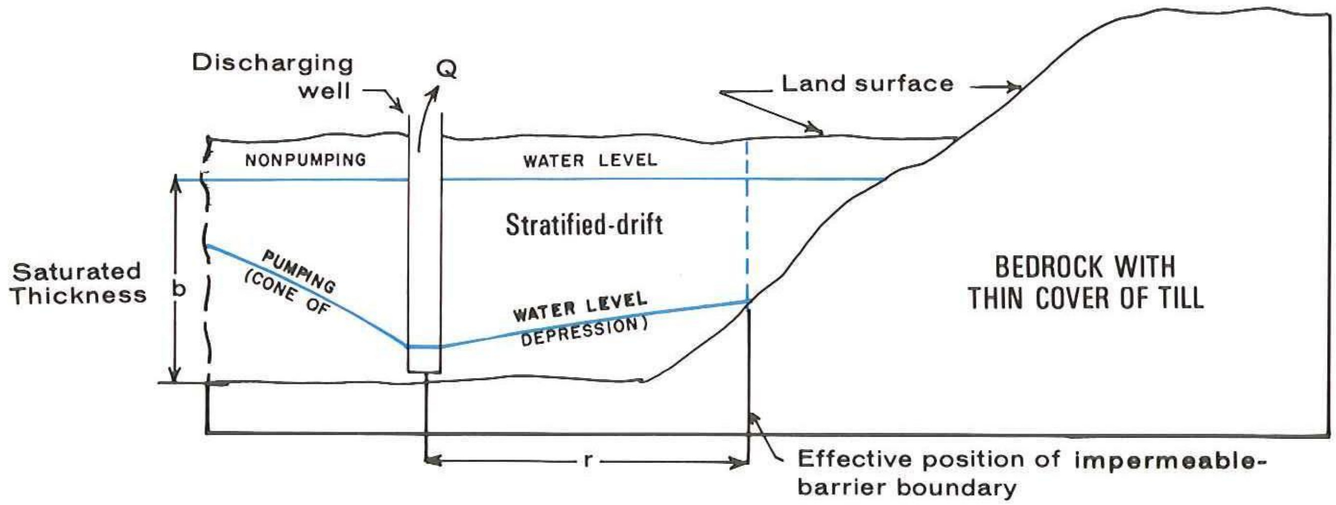
Hydraulic boundaries

Hydraulic boundaries limit the continuity of an aquifer, thereby affecting water-level changes in time and space that occur as a consequence of aquifer development. The two types, termed impermeable-barrier boundaries and line-source boundaries, and their effect on the response of an aquifer to pumping, are fully described by Ferris and others (1962). Valley walls formed of till and bedrock are considered to constitute impermeable-barrier boundaries for the adjacent stratified-drift aquifers in the basin, as shown in figure 25. The hydraulic conductivity of till and bedrock are generally low in contrast to stratified drift and there is relatively little flow across the interface between these materials. To simplify subsequent analysis of the hydrologic effect of such boundaries, they are idealized as straight lines approximately coincident with the 10-foot saturated-thickness lines (plate B).

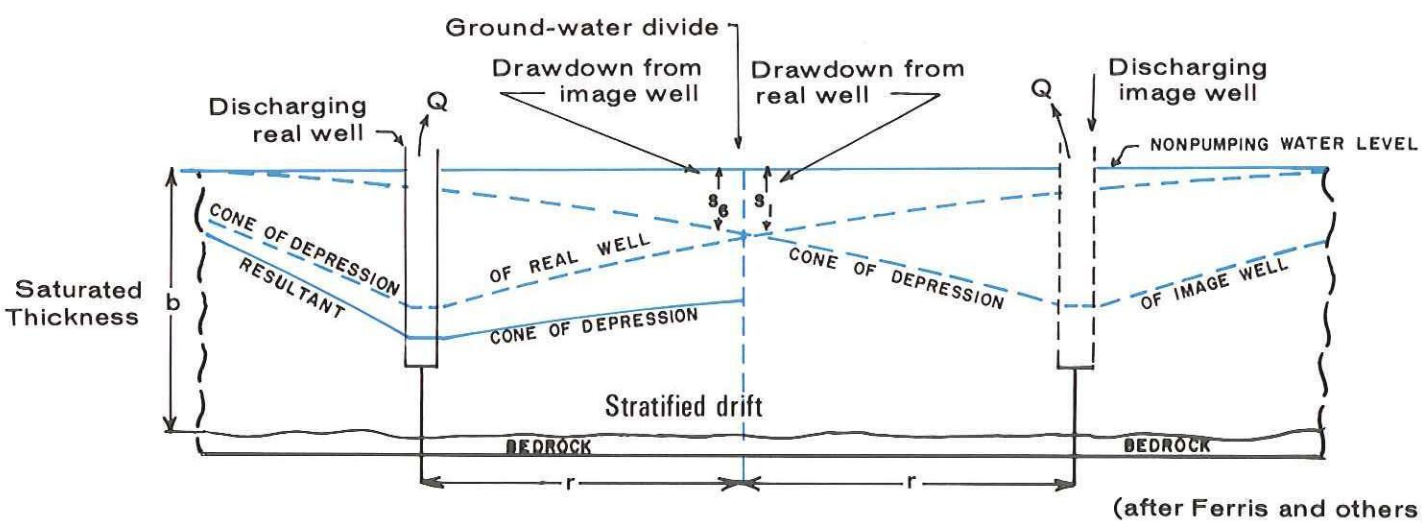
Major perennial streams or large lakes hydraulically connected to stratified-drift aquifers are considered line-source boundaries (Fig. 26). In subsequent analyses, they also are idealized as straight lines coincident with the trend of the streams. Because the rivers and lakes in the basin do not penetrate the full thickness of the aquifer, it is not possible to accurately define the effective location of a line-source boundary without performing detailed site tests.

Most stratified drift in the basin was deposited in valleys and lowlands and overlies bedrock or till-mantled bedrock. Therefore, the stratified drift is bounded both laterally and at depth by these generally less permeable materials.

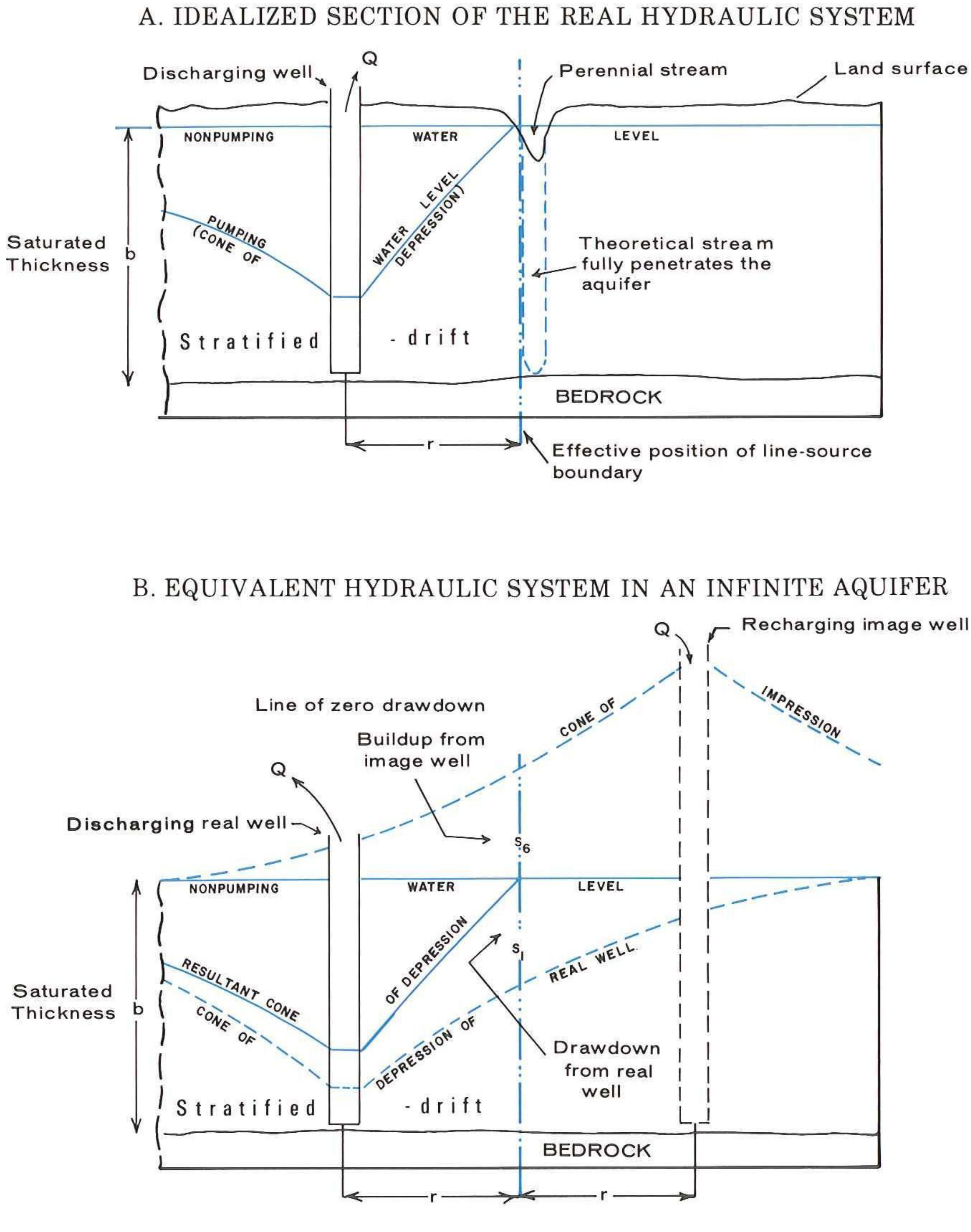
A. IDEALIZED SECTION OF THE REAL HYDRAULIC SYSTEM



B. EQUIVALENT HYDRAULIC SYSTEM IN AN INFINITE AQUIFER



(after Ferris and others, 196



(after Ferris and others, 1962)

Figure 26.--Effects of a line-source boundary on a stratified-drift aquifer

Although water moves through till and bedrock, the amount is small in contrast to that moving through equivalent volume of stratified drift. The contact between the saturated till and bedrock and the stratified drift as previously mentioned is considered to act as a barrier across which there is no flow. Yields of wells tapping stratified drift in the proximity of such boundaries are less than if the aquifer were of infinite extent. As shown on figure 25, the net effect is to lower the water level on the side adjacent to the boundary more than on the opposite side of the pumping well. More drawdown is required to obtain the same yield as would result if the boundary were absent, or conversely, less water will be pumped for the same equivalent drawdown.

The mathematical analysis of drawdowns in this situation is modeled by assuming that there is a discharging well (termed "image well") located equidistant on the opposite side of the barrier boundary, on a line through the real pumping well and perpendicular to the boundary. The drawdowns produced by each real well and image well then are calculated for any point of interest. The two drawdowns are added at each point to obtain the resultant cone of depression shown on figure 25.

Streams traversing the valley floors may act as a line-source boundary for the adjacent stratified-drift aquifer. In such places, pumping from wells will reverse the natural ground-water gradient to streams and induce the surface water to infiltrate the aquifer. Aquifer-stream relationships and the effectiveness of streams as line-source boundaries in this area are discussed further on pp. 37-39.

The mathematical analysis of drawdowns in this situation is modeled by assuming the existence of a recharging image well, located equidistant on the opposite side of the boundary, and on a line through the real pumping well and perpendicular to the boundary (stream). The image well is assumed to be injecting water at a rate equal to that withdrawn by the real pumping well, so that the resulting drawdown is zero at the line-source boundary. Under these conditions, the drawdowns in the vicinity of the wells can be calculated to determine the shape and depth of the resultant cone of depression as shown in figure 26.

Along the coast, the saltwater-freshwater interface represents a boundary condition that may present water-quality problems. As noted earlier, pumping near such a boundary often reverses the gradient and much of the pumped water is supplied by induced recharge of surface water. In this hydrologic setting, pumping will likely result in (1) landward movement of the interface between fresh and salty ground water, (2) the induced recharge of salt water from the ocean into the aquifer and, eventually, (3) contamination of the well. Locating wells as far away as possible from the salt water, tapping the upper part of the saturated zone and reducing pumping rates are some of the measures that are commonly taken to reduce the likelihood of salt-water intrusion and contamination.

Recharge

Natural recharge to aquifers is derived from precipitation that falls within the basin boundaries. The amount of water that infiltrates the soil and reaches the saturated zone depends upon many factors, such as (1) intensity and duration of rainfall, (2) soil types, (3) vegative cover, (4) season, and (5) land slope.

As previously mentioned, natural recharge from precipitation occurs mainly from October to April (fig. 22). The amount of ground water in storage at the start of the annual period of little or no recharge (growing season) is significant in respect to potential withdrawals. Records of long-term observation wells in Connecticut indicate that, under natural conditions, the annual recharge from precipitation has been generally adequate to replenish ground water naturally discharged from storage.

The amount of recharge also can be increased or decreased by man's activities. Increasing recharge may involve lowering the water table by pumping or installation of drainage facilities. This removes ground water from storage and thereby provides more space for recharge that might otherwise have been rejected. Pumping also reverses the water-table gradient near streams or other surface-water bodies, causing surface water to move into the aquifer and toward the well. This process, to be subsequently discussed, is termed "induced infiltration" and the resulting recharge is termed "induced recharge".

Manmade facilities for artificially recharging aquifers have also been constructed in and adjacent to the study area. These facilities include basins above the water table that collect stormwater runoff or surface water from streams and allow it to infiltrate to the saturated zone, and recharge wells that inject water directly into the saturated zone. Other minor facilities that contribute to induced recharge include septic leaching fields, dry wells, leaky water lines, sewers, and storm-water drains.

Natural recharge to stratified drift.--Natural recharge to stratified drift aquifers consists of (1) precipitation that infiltrates into this unit and percolates to the water table, and (2) surface water that percolates into the stratified drift from the adjacent till-bedrock uplands. Where ground-water withdrawals are greater than the average annual natural recharge, there will be a resulting net decrease of water in storage and corresponding decline in ground-water levels.

Natural recharge can be determined by measuring and summing the components of ground-water discharge over a period in which there is no net change in ground-water storage. Ground-water outflow--the sum of ground-water runoff, evapotranspiration, and underflow--accounts for the major part of ground-water discharge from areas where there is little or no pumpage and has been used as a conservative estimate of natural recharge (Randall and others, 1966; Ryder and others, 1970, Cervione and others, 1972).

Hydrologic studies in nonurbanized areas elsewhere in Connecticut show that the amount of ground-water outflow from a basin is related to the proportion of stratified drift it contains (Randall and others, 1966; Thomas and others, 1967; Ryder and others, 1970; Cervione and others, 1972; Wilson and others, 1974; Mazzaferro and others, 1979). Figure 27 from Mazzaferro and others, (1979, fig. 38) shows the relation between the percentage of total basin area underlain by stratified drift and the average annual ground-water outflow. The data were derived from 27 small drainage basins in Connecticut, Massachusetts, and New York. The scatter of points about the line probably is due to a combination of (1) poor approximation of ground-water outflow, (2) inclusion of upland areas of unsaturated stratified drift, (3) changes in ground-water storage over the period of analysis, (4) areal differences and annual variations in the amount of ground-water evapotranspiration, and (5) unmeasured ground-water discharge from pumping. The line of relation in figure 27 was developed by linear regression and is described by the equation:

$$Y = 35 + 0.6X,$$ Where

Y = ground-water outflow as a percentage of total runoff, and

X = percentage of total basin area underlain by stratified drift.

This equation was used to determine the average annual ground-water outflow and the ground-water outflow equaled or exceeded 7 years in 10 from stratified-drift deposits in nonurbanized areas. The methodology for use of this equation, together with the information from plate B and figures 9 and 27, is as follows:

1. Determine from plate B the areal extent of the stratified-drift aquifer and delineate the adjacent till and bedrock drainage area from which ground water flows into the stratified drift.

2. Measure the total area delineated and the area of stratified drift, in square miles. Compute the percentage of the total area underlain by stratified drift.

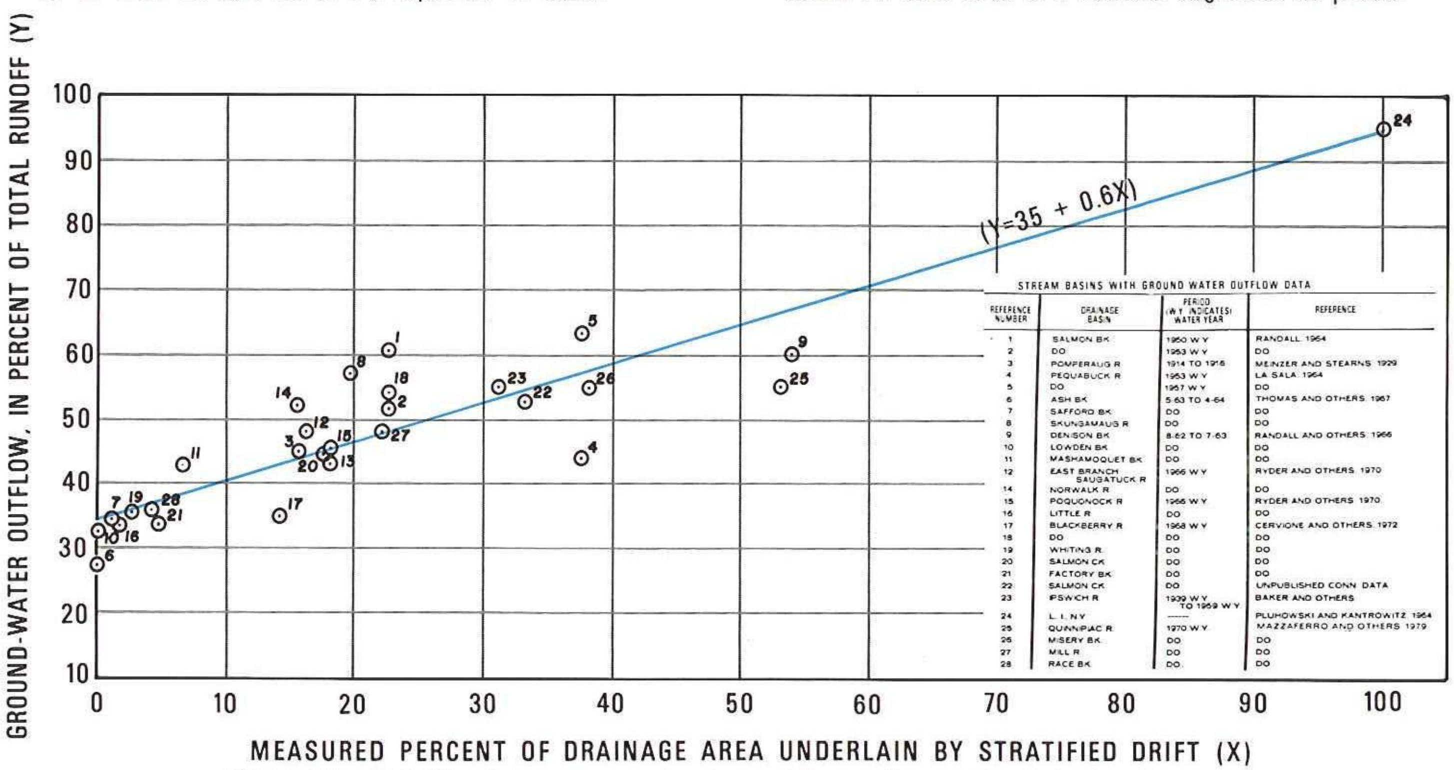
3. Calculate ground-water outflow (Y) as a percentage of mean annual runoff from equation Y = 35 + 0.6X.

4. Calculate mean annual runoff as determined from figure 9. Runoff = Ratio x 1.16 Mgal/d/ft^2 x drainage area (step 1).

5. Calculate average annual ground-water outflow (step 3 x step 4).

6. Calculate ground-water outflow equaled or exceeded 7 years out of 10 (0.7 x step 5).

Induced recharge to stratified drift.--As previously mentioned, sustained pumping of wells tapping stratified drift can lower the water table beneath an adjacent stream or lake, thereby inducing recharge from the surface-water body to the aquifer. Many industrial and municipal-supply wells in this area are located adjacent to peren-



REFERENCE NUMBER	DRAINAGE BASIN	PERIOD (W Y INDICATES) WATER YEAR	REFERENCE
1	SALMON BK	1960 W Y	RANDALL 1964
2	DO	1953 W Y	DO
3	POMPERAUG R	1914 TO 1916	MEINZER AND STEARNS 1929
4	PEQUABUCK R	1953 W Y	LA SALA 1964
5	DO	1957 W Y	DO
6	ASH BK	5-63 TO 4-64	THOMAS AND OTHERS 1967
7	SAFFORD BK	DO	DO
8	SKUNGAMAUG R	DO	DO
9	DENISON BK	8-62 TO 7-63	RANDALL AND OTHERS 1966
10	LOWDEN BK	DO	DO
11	MASHAMOQUET BK	DO	DO
12	EAST BRANCH SAUGATUCK R	1966 W Y	RYDER AND OTHERS 1970
14	NORWALK R	DO	DO
15	POQUONOCK R	1966 W Y	RYDER AND OTHERS 1970
16	LITTLE R	DO	DO
17	BLACKBERRY R	1968 W Y	CERVIONE AND OTHERS 1972
18	DO	DO	DO
19	WHITING R	DO	DO
20	SALMON CK	DO	DO
21	FACTORY BK	DO	DO
22	SALMON CK	DO	UNPUBLISHED CONN DATA
23	IPSWICH R	1939 W Y TO 1959 W Y	BAKER AND OTHERS
24	L I N Y	------	PLUHOWSKI AND KANTROWITZ 1964
25	QUINNIPIAC R	1970 W Y	MAZZAFERRO AND OTHERS 1979
26	MISERY BK	DO	DO
27	MILL R	DO	DO
28	RACE BK	DO	DO

Figure 27.--Relation between ground-water outflow and percent of drainage area underlain by stratified drift

nial streams. These streams are hydraulically connected to the stratified-drift aquifer and the wells consequently obtain much of their water from induced recharge.

In pumped wells, located near surface-water bodies, the water is initially withdrawn from storage; then, as the cone of depresion continues to spread, water from an increasing area flows toward the well. When the water table in the vicinity of the nearby stream is sufficiently lowered by pumping, more and more ground water that would have naturally discharged to the stream is diverted and captured by the well. Eventually, water levels may be lower than the adjacent surface-water body and the aquifer is recharged by induced infiltration (fig. 26). Salt-water intrusion, mentioned in the preceding section on hydraulic boundaries, can be considered an analogous process.

Although recharge by induced infiltration and the factors controlling it are well known, it is difficult to evaluate quantitatively in the study area. Nevertheless, an understanding of the controlling factors provides a basis for determining the optimum sites for ground-water development.

Potential induced recharge can be estimated by using a modified form of Darcy's equation (Walton and others, 1967, p. 4), as follows:

$$R_I = 7.48 I_t S_r A_r,$$

where

R_I = potential recharge by induced infiltration, in gallons per day,

I_t = average infiltration rate per square foot of streambed per foot of head loss, for a particular surface-water temperature, in cubic feet per day per square foot per foot,

S_r = average head loss over the infiltration area or average depth of water in the stream for a particular stream stage, depending upon whether the water table is above or below the streambed, in feet, and

A_r = infiltration area of streambed, in square feet.

The average infiltration rate, I_t, under conditions of constant temperature and gradient, is controlled by the vertical hydraulic conductivity of the streambed deposits. Although the materials underlying streams hydraulically connected to a stratified-drift aquifer may be described in general terms as silty, sandy, or gravelly, they are, in detail, a complex assemblage of inorganic and organic-rich sediments; the thickness and composition may be changed periodically by erosion or deposition.

As the vertical hydraulic conductivity is related to sediment size and stratification, the yield of a nearby well can be significantly affected if these properties change with time. Deposition of fine-grained sediments behind a new dam may eventually lower nearby well yields, whereas a flood flow may erode fine-grained sediments, thereby exposing coarser materials and increasing induced recharge.

Infiltration rates also vary with the temperature of the surface water. A change in the temperature of the water changes the viscosity and thus the infiltration rate. Temperature-induced changes in infiltration rates can be computed by use of the temperature viscosity relationship shown on figure 28, which gives the conversion factors for adjusting laboratory hydraulic conductivities to field conditions. Variations in temperature of water in the Connecticut River range from 0°C to 33°C and indicate that, for a constant stream stage, the infiltration rate may be as low as 67 percent and as high as 160 percent of the rate for the median temperature of about 13°C.

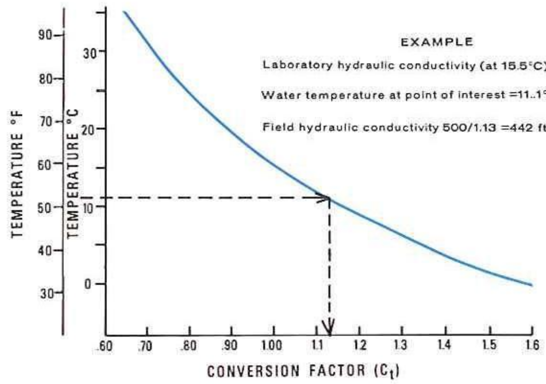


Figure 28.--Factors for adjusting laboratory hydraulic conductivity to field values

Infiltration rates or vertical hydraulic conductivities of streambed sediments have not been determined in this area, and detailed site studies are necessary to quantitatively assess the potential induced recharge at any specific location. However, the most favorable infiltrating conditions are likely along non-ponded streams where streambed deposits consist of clean sand and gravel. At sites where poorly-sorted gravel exists, infiltration rates as much as 105 gal/d/ft^2/ft have been reported from elsewhere in Connecticut (Cervione and others, 1972, p. 50; Wilson and others, 1974, p. 34; Ryder and others, 1970, p. 28). In Rhode Island, infiltration rates at a temperature of 15.6°C were reported by Gonthier and others (1974, p. 15) to range from 1 to 5 gal/d/ft^2/ft for fine-grained sediments and 5 to 20 gal/d/ft^2/ft for coarse-grained streambed materials.

The average hydraulic gradient (S_r) can also change significantly. Under conditions of high flow, the stream stage may be much higher than at low flow and cover a much greater area. Other factors that should be considered in respect to induced recharge are as follows:

1. Quality of ground water may be affected, particularly by infiltration of brackish or salty surface water.

2. Streamflow may be reduced. Where the infiltration capacity is greater than the low-flow volume of the stream, the pumping of wells may dry up sections of the stream for certain periods of time. Conversely, as induced infiltration cannot exceed the amount of water in the stream, the low flow of the stream is the limiting constraint on ground-water development at some localities.

3. The amount of induced recharge can be limited by a low transmissivity of the aquifer--its ability to transmit water from the stream to the well.

Estimating well yields

Water is withdrawn from stratified drift aquifers by drilled, dug, and driven wells, which differ in depth, diameter, finish, and other construction details. The techniques commonly used in constructing such wells are given by Johnson (1966). Most wells tapping stratified drift that yield more than 50 gal/min, are (1) drilled or dug, (2) 6 inches or more in diameter, and (3) finished with a screen (hereafter termed screened wells). Fifty-three such wells, inventoried during this basin study (Bingham and others, 1975), yield from 2 to 1570 gal/min and have a median yield of 397 gal/min (table 16). The specific capacities of these wells, determined from reported data, range from 0.03 to 120.8 gal/min/ft with a median value of 22.4 gal/min/ft.

The evaluation of areas favorable for ground-water development is based on estimating the yields of hypothetical screened wells tapping these aquifers. The procedure involves determining the drawdown in a well (or wells) for a given constant pumping rate for 180 days without recharge. If, after this period, the water level in the well is above the top of the well screen, continuous pumping at the proposed rate is considered feasible. A 180-day pumping period is used, as it approximates the longest known period of little or no ground-water recharge in the basin. The maximum available drawdown in a well is considered to be equal to the thickness of saturated material above the top of the screen and can be determined from Plate B. For example, at a site on Plate B where the average saturated thickness is 100 feet and the screen is set in the lower 30 feet, the maximum available drawdown is 70 feet.

An estimate of the yield of a screened well tapping stratified drift can be made at any site where the hydraulic characteristics of the aquifer and the approximate location of hydraulic boundaries are known. The saturated thickness and transmissivity data for many sites in stratified drift are shown on plate B, and the method used to determine the drawdown in a well is outlined below.

Estimating drawdown

The drawdown in a pumping well that taps a stratified-drift aquifer includes at least three, and may include all, of the following components:

s_a, the aquifer drawdown for a specific discharge and transmissivity.

sd, drawdown due to dewatering of the aquifer.

s_p, drawdown due to partial penetration of the aquifer.

s_e, drawdown due to moving water from the aquifer into the well, termed entrance loss.

s_i, drawdown due to pumping of other wells.

s_b, drawdown due to impermeable-barrier boundaries.

s_r, buildup due to line-source boundaries.

For a specific well discharge, Q, the total drawdown in the pumping well can be expressed as:

$$s_{total} = s_a + s_d + s_p + s_e + s_i + s_b - s_r$$

The aquifer drawdown, s_a, is computed by the Theis equation (Theis, 1935, p. 520; Ferris and others, 1962, p. 92) as follows:

$$s_a = \frac{Q}{4\pi T}\int_{\frac{r^2S}{4Tt}}^{\infty} \frac{e^{-u}}{u}\,du$$

where $u = r^2S/4Tt$,

s_a= aquifer drawdown, in feet, at any point of observation in the vicinity of a well discharging at a constant rate ,

Q = constant well discharge, in ft^3/d ,

T = transmissivity, in ft^2/d ,

r = distance in feet, from the center of the discharging well , to the point of observation,

S = storage coefficient, and

t = time, in days, since pumping started.

When determining the aquifer drawdown in the pumping well itself, the distance, r, is generally taken as equal to the well radius. Figure 29 shows the relationship between aquifer drawdown (s_a) in a pumping well and various discharge rates (Q), calculated for transmissivities (T) of 1,000, 2,000, 5,000, 8,000, 12,000, and 16,000 ft^2/d; radius of well (r) of 1 foot; average storage coefficient (S) of 0.2; and time of 200 days since pumping began.

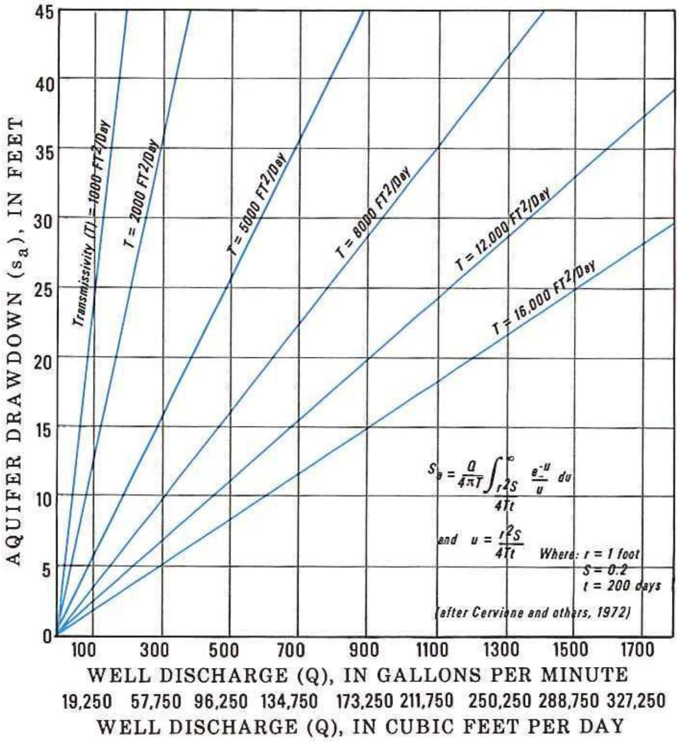


Figure 29.--Relation between aquifer drawdown and well discharge in screened wells

Impermeable-barrier and line-source boundaries limit the hydraulic continuity of an aquifer. Figures 25 and 26 illustrate how boundary conditions are equated to a system of infinite areal extent by use of recharging and discharging image wells. Different configurations of boundaries and pumping wells can also be made hydraulically equivalent to an aquifer of infinite areal extent by use of arrays of image wells (Ferris and others, 1962, p. 144). The drawdown (s_b) or buildup (s_r) of the water table produced by the resulting image wells can be estimated from figure 30 or calculated by the Theis equation.

The drawdown in a well can be approximately adjusted for dewatering the aquifer by the following equation (Jacob, 1944; Walton, 1962, p. 7):

$$s' = s - (s^2/2b)$$

Where

s' = the drawdown, in feet, that would occur if the saturated thickness of the aquifer did not decrease (equal to s_a as previously defined),

s = observed drawdown, in feet, under water-table conditions (equal to $s_a + s_d$, as previously defined), and

b = initial saturated thickness of the aquifer, in feet.

The drawdown due to dewatering, s_d, is equal to $s - s'$ in the preceding equation. Figure 31 is a graph that can be used to quickly find the additional drawdown due to the effects of dewatering the aquifer; it relates values of s_d to values of s_a for representative saturated thicknesses ranging from 20 to 120 feet.

A correction for partial penetration is also needed because most wells in stratified drift are

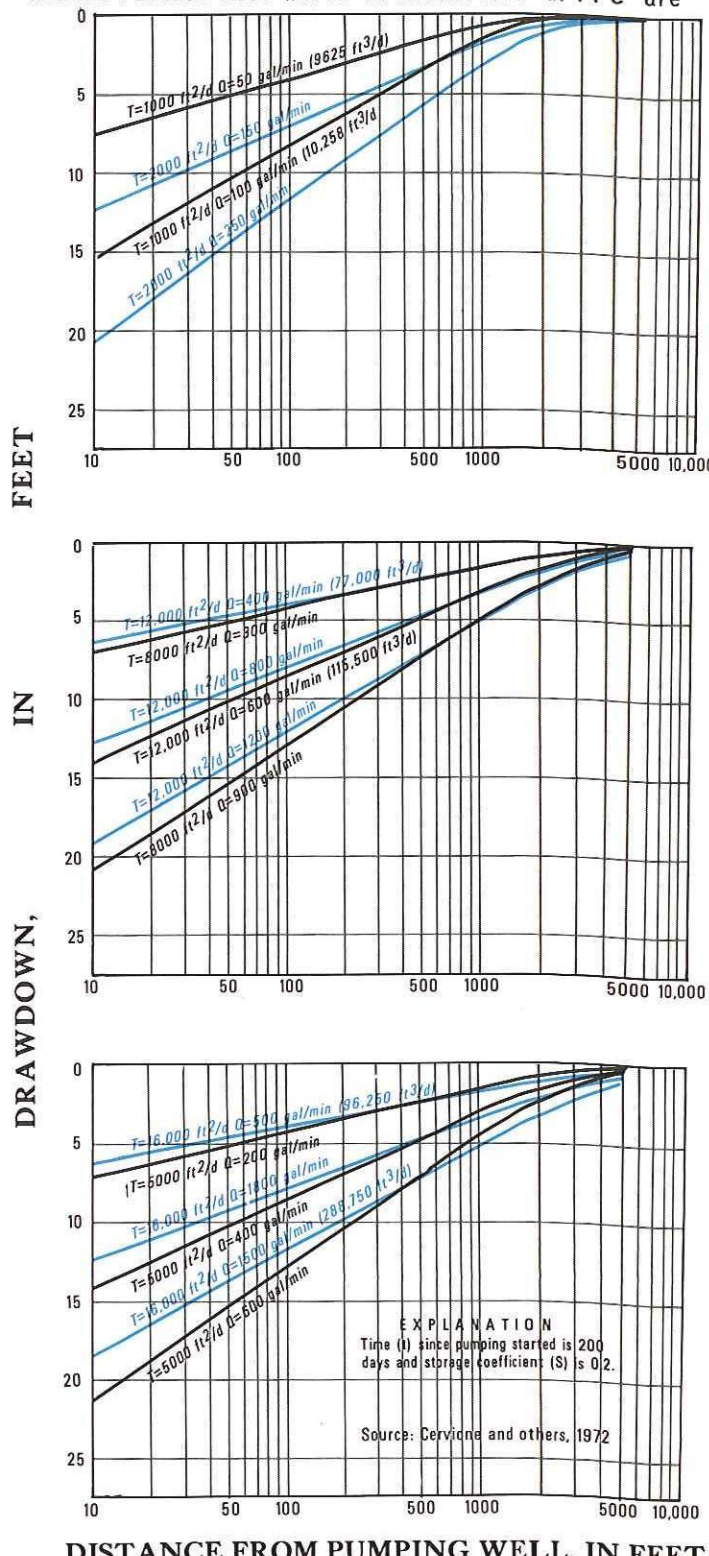


Figure 30.--Distance-drawdown curves for selected values of transmissivity (T) and pumping rates (Q)

screened in only the lower part of the saturated section. This results in a convergence of flow to the screen. The drawdown in a pumping well can be approximately adjusted for the effects of this partial penetration by the following equation (Walton, 1962, p. 8):

$$\frac{s_a}{C_{pp}} = s'',$$

where

s_a = the aquifer drawdown, in feet, for a well screened and open to the entire saturated thickness of the aquifer (fully penetrating well),

s'' = the drawdown, in feet, for a partially penetrating well (equal to $s_a + s_p$, as previously defined), and

Cpp= the correction factor for partial penetration (dimensionless).

Approximate values of partial-penetration-correction factor, Cpp, can be obtained from figure 32 for selected values of saturated thickness. A K_v/K_h ratio of 0.1 and a well radius of 1 foot were assumed for this graph which is based on the equation developed by Kozeny (Butler, 1957, p. 160).

The drawdown required to move the water from the aquifer into the well, termed entrance loss (s_e), is related to screen design, slot size, and well development (Johnson, 1966, p. 128-130). The data required to determine this component of total drawdown were not available. Therefore, in computing yields in the subsequent section of this report, the wells are assumed to be 100-percent efficient, and no drawdown correction for entrance loss is made.

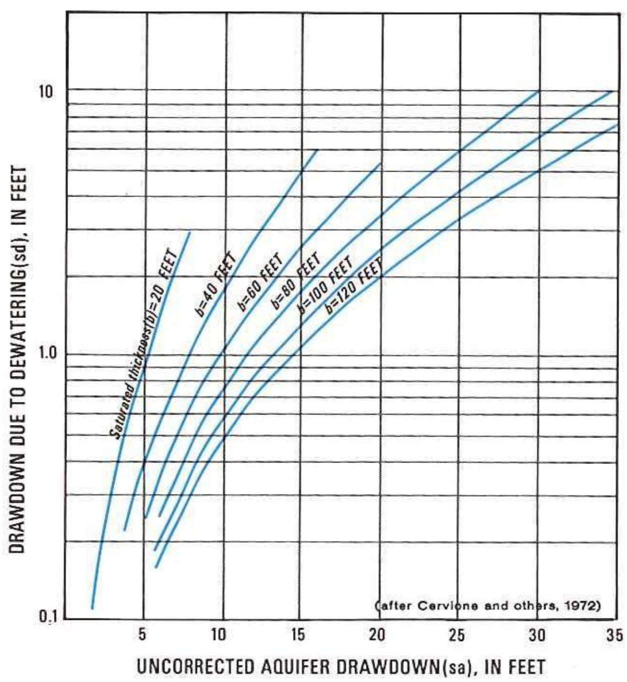


Figure 31.--Drawdown correction for dewatering of an aquifer.

The Theis equation and other equations used to evaluate the components of drawdown are based on a constant value of transmissivity, but when pumping produces substantial thinning of the saturated part of an aquifer, transmissivity may decrease significantly. For this reason, it is rarely possible to exactly determine the maximum potential yield of a well tapping stratified drift--that is, the pumping rate that would lower the water level in the well to just above the top of the screen after 180 days of pumping.

The theoretical effects of well radius and percentage of aquifer screened on well yield are illustrated in figure 33. Use of a longer well screen decreases the maximum permissible drawdown, if the limit used in this report (1 foot above the top of the screen) is applied, but it also decreases the head losses due to partial penetration. When up to about 40 percent of the aquifer is screened, the decreased partial penetration losses are more than sufficient to offset the lower operating drawdown, resulting in a higher well yield. At greater screened percentages, the decrease in available operating drawdown offsets the lower partial penetration losses, and well yield begins to decrease. On the other hand, if operating drawdown is not restricted to the top of the screen, increasing the screened length should produce corresponding increases in yield. The assumption is made that the aquifer is homogeneous and the length of well screen can be arbitrarily increased, a situation that is uncom-

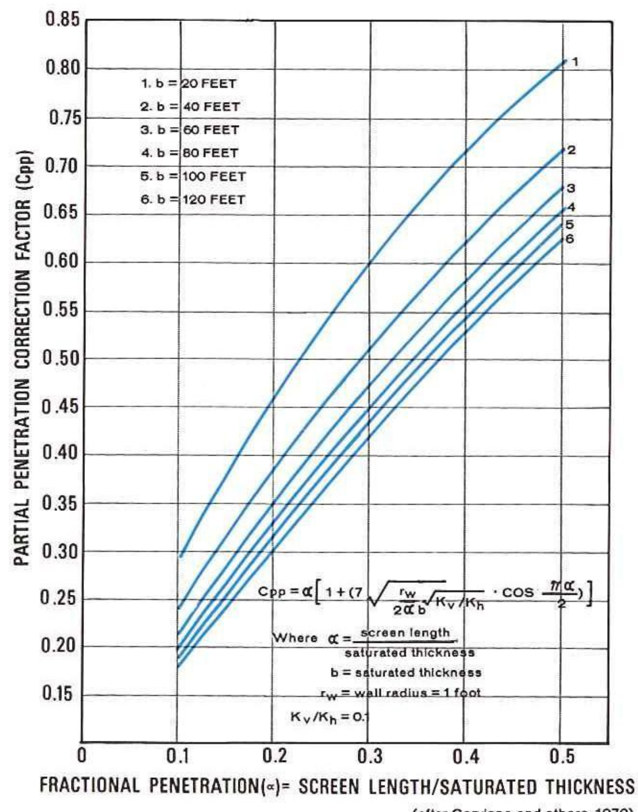


Figure 32.--Correction factor for partial penetration for selected values of saturated thickness and fractional penetration

mon. The curves in figure 33 also show that doubling the well radius from 0.5 foot to 1.0 foot increases the yield by about 10 percent.

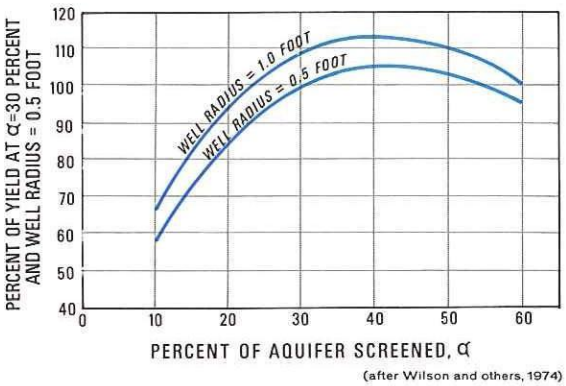


Figure 33.--Well yield related to percentage of aquifer screened and to well radius

Analytical Models of Favorable Areas

Future water-resources planning and management require the identification and delineation of aquifers capable of yielding large quantities of water for public or industrial supply. Stratified-drift aquifers in 12 areas shown on plate D are considered to be the most favorable for development of large ground-water supplies in the study area. The long-term yields in these 12 favorable ground-water areas were estimated by use of analytical models and are listed in table 20. Many other areas underlain by coarse-grained stratified drift (plate B) may also yield large quantities of ground water, but on the basis of available data, they will not sustain a yield of 1 Mgal/d or more for 180 days.

The quantity of water potentially available in the favorable groundwater areas is considered to be the sum of (1) the ground-water outflow that is equalled or exceeded 7 years in 10, from the favorable area, and from adjacent till and bedrock areas, and (2) the 90-percent flow duration of streams entering the area.

The method for determining the ground-water outflow equaled or exceeded 7 years in 10 is discussed on pages 34-35. The 90-percent flow duration of streams that enter the favorable areas can be computed by use of plate B and figures 9 and 27. These data were used to develop the curves in figure 34 that show the size of drainage basin and percentage of drainage area underlain by stratified drift required to produce 90-percent-duration streamflows of 0.5, 1.0, and 2.0 Mgal/d under natural conditions.

The ground-water outflow and streamflow parameters, selected as indices of the quantity of water potentially available, provide a practical management limit to the stress on a stream-aquifer system. Withdrawal of this amount of water could dry up an adjacent reach of stream approximately 10 percent of the time but would not result in a long-term decrease in ground-water storage. Alternative management schemes that utilize low-flow augmentation, artificial recharge, or increased withdrawal rates during periods of high streamflow would require different estimates of the total quantity of water potentially available.

In the analytical models, the hydraulic boundaries of the stratified-drift aquifer underlying each favorable area were idealized as straight lines, that approximate the 10-foot saturated-thickness line on plate B, are coincident with the limits of the saturated coarse-grained material or are coincident with the position of major streams. The average transmissivity within these boundaries was estimated based on available data for saturated thickness and average hydraulic conductivity at sites of wells and test holes. The Connecticut River is considered a line-source boundary for adjacent favorable areas. At other sites traversed by perennial streams, the effectiveness and position of line-source boundaries are uncertain and two analytical models were made for these areas. In one model, the stream was considered to fully penetrate the aquifer and a line-source boundary was positioned approximately coincident with the stream. The second model contained only impermeable-barrier boundaries. The long-term yields corresponding to the two models represent estimated maximum and minimum values for each area.

Hypothetical wells were located in the thickest and most transmissive sections of the aquifer models and as close as feasible to any streams. The hypothetical wells are all 24-inch diameter (except in one model which has 48-inch effective diameter) are screened in the lower three tenths (0.3) of the aquifer, and are 100-percent efficient. For these modeled areas, the ratio of vertical to horizontal hydraulic conductivity (K_v/K_h) is assumed to be 0.1, and the long-term storage coefficient is 0.2.

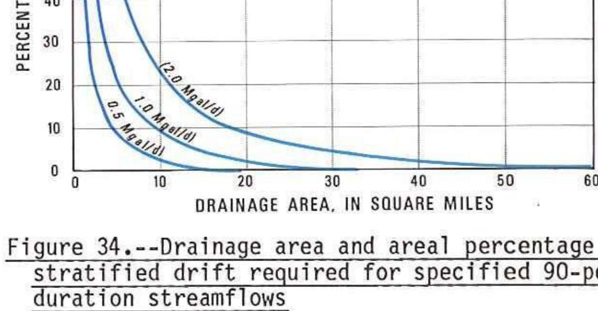


Figure 34.--Drainage area and areal percentage of stratified drift required for specified 90-percent duration streamflows

Table 20.--Summary of yields calculated from analytical models of areas favorable for supporting ground-water withdrawals of about 1 million gallons per day or more

Favorable area: Location	Model No. on plate C	Ground-water outflow from model subarea: Area of strip aquifer (mi^2)	Total ground-water outflow area (mi^2)	Percent of model drainage area under-lain by strati-fied drift	Ground-water outflow equaled or exceeded 7 yrs in 10 (Mgal/d)1/	Flow of principal streams entering modeled favorable area equaled or exceeded 90 percent of time (Mgal/d)2/	Pumpage from modeled aquifer during 180-day no-recharge period (Mgal/d)	Recharge induced from stream to sustain pumpage (Mgal/d)3/	Remarks
Maromas	1A	2.9	7.5	38	4.8	>10 (Conn. R.)	4.4	0.8	Aquifer and river capable of transmitting more than modeled pumpage.
	2A	0.1	3.5	2.9	1.2	>10 (Conn. R.)	0.8	0	do.
Haddam Meadows	3A	0.6	1.6	37	1.02	>10 (Conn. R.)	3.7	2.9	
Tylerville	4A	0.7	1.38	51	0.98	>10 (Conn. R.)	4.3	3.6	
Eightmile River (North Plain area)	5A	1.25	5.25	24	2.9	7.0	2.12	0.82	Aquifer will supply modeled pumpage without inducing recharge.
	5B	1.25	5.25	24	2.9	-	1.3	-	No recharge boundary in model.
Eightmile River (Pleasant View area)	6A	0.38	0.69	55	0.5	8.0	0.82	0.45	
	6B	0.38	0.69	55	0.5	-	0.51	-	No recharge boundary in model.
Eightmile River (North Lyme area)	7A	0.31	1.44	22	0.78	8.1	1.2	0.62	
	7B	0.31	1.44	22	0.78	-	0.52	-	No recharge boundary in model.
East Branch Eightmile River	8A	0.69	3.0	23	1.62	1.6	1.15	0	
	8B	0.69	3.0	23	1.62	-	0.36	-	No recharge boundary in model.
Falls River (Centerbrook area)	9A	0.08	0.14	56	0.1	1.75	0.37	0.3	Aquifer limited, but suited for induced recharge.
Rogers Lake	10A	0.08	0.06	100	0.06	1.0 (Rogers Lake, 0.5 mi^2)	2.38	2.3	do.
Hammonasset River (north area)	11A	1.0	3.75	27	2.14	3.7	1.38	0	Aquifer and river capable of transmitting more than modeled pumpage.
	11B	1.0	3.75	27	2.14	-	0.6	-	No recharge boundary in model.
(south area)	12A	0.31	0.84	37	0.53	4.9	2.1	1.7	
	12B	0.31	0.84	37	0.53	-	1.0	-	No recharge boundary in model.

1/ From figure 27.

2/ From figs. 9 and 15; converted to Mgal/d from ($ft^3/s/mi^2$) (drainage area, mi^2) $\div$ 1.54.

3/ Obtained by subtracting 75 percent of ground-water outflow from modeled pumpage. "B" models infer no line-source boundary; however, subtracting "B" pumpage from "A" pumpage implies there is induced recharge for "A" models.

The analytical models were used to determine the maximum withdrawal defined as the rate that the aquifer, as simplified, could sustain under constant pumping for 180 days without recharge and without lowering the pumping water level to less than 1 foot above the top of the well screen. During the remainder of the year, about 185 days, most natural recharge occurs, and the aquifer is assumed to be capable of sustaining this yield with even less drawdown. The average annual yield would be derived from the capture of ground-water outflow and induced recharge from streams. Details on the analytical procedure used to compute aquifer yields from such a model are given by Mazzaferro and others, (1979, p. 51-54).

The 12 favorable ground-water areas (shown on plate D) met the following criteria: (1) aquifer is generally composed of coarse-grained stratified drift, (2) aquifer has saturated thickness of 40 feet or greater (see plate B), and (3) streamflow entering the area 90 percent of the time is at least 1 million gallons per day.

Table 20 summarizes the results of the analysis of each modeled area. The aquifer conditions, well spacing, and boundary positions are shown on plate D. The well-field geometry and hydraulic-boundary positions utilized in each model may not, however, represent the optimum arrangement in respect to maximizing the aquifer yield. To the extent that the wells are not located in an optimum configuration and the boundary positions are idealized, the computed yields may be somewhat less than under real conditions. Conversely, the effective position of hydraulic boundaries in the models may be more "optimum" than under real conditions and the computed yields may be greater than they actually would be.

TILL

Till, the most extensive unconsolidated deposit in the area, forms a widespread, discontinuous mantle over much of the bedrock. Outcrops of bedrock are common in upland areas where till is thin but are not delineated on plate B because of the small scale. The thickness of till ranges from 0 to 150 feet, with a median thickness of 26 feet estimated from information reported for 467 bedrock wells. Areas where till is more than 40 feet thick are scattered throughout the basin and are defined separately on plate B.

Most till in the uplands is thin and above the water table at least part of the year and, therefore, not a dependable aquifer. Where thick or favorably located in swales or valleys, it can provide low yields to large diameter dug wells. Till may locally contain lenses of sorted sand and gravel that enhance its ability to provide an adequate domestic supply.

The hydraulic conductivity of till is variable over about 4 orders of magnitude: The results of 31 laboratory measurements of samples from New England range from 0.013 to 29 feet per day with a median of 0.67 feet per day (Allen and others, 1963; Randall and others, 1966; Sammel and others, 1966; Thomas and others, 1967).

Seasonal fluctuations of the water table in upland areas are relatively large. Because of the generally low hydraulic conductivity of till, drawdowns resulting from pumping are also large. Accordingly, optimum conditions for the installation of a dug well generally require excavation through 10 feet or more of perennially saturated till to lessen chances of well failure during dry seasons.

Storage in a dug well is an important supplement to its yield. When water is withdrawn from a well, it is replaced by inflow from the aquifer. In a 3-foot diameter dug well tapping till, there are about 53 gallons for each foot the well extends below the water table. If the saturated thickness is 10 feet, the storage is 530 gallons, and should this quantity of water be pumped out, most will be replenished in about 10 hours, if the hydraulic conductivity is equivalent to the median value of 0.67 feet per day.

BEDROCK

Thousands of domestic, commercial and small industrial wells tap bedrock aquifers for water supply in areas not served by a public utility. The three bedrock units in the basin-- sedimentary, igneous, and metamorphic crystalline rock-- are briefly described in table 15 and their areal distribution is shown on plate C. The sedimentary and igneous rocks, while geologically and hydrologically dissimilar, are interbedded as shown in the cross-section on plate C, and are hydraulically connected. Detailed information on the distribution, lithology, and geologic history of the rocks is contained in the published and unpublished quadrangle maps and reports indexed on plate C.

Occurrence of Ground Water in Bedrock

Joints and other types of fractures such as faults in the igneous and crystalline bedrock provide the open space for storage and movement of ground water. The sedimentary bedrock, in addition to having various types of fractures, has open spaces along the bedding planes and in intergranular pores (primary openings). However, some of these primary openings have been filled with a mineral cement and do not store or transmit water.

The distribution and width of the fractures and joints in the bedrock varies areally and vertically. At some localities, a detailed knowledge of the orientation of the major joints will be useful in selecting a well site most likely to produce an adequate domestic supply. However, in most areas, the random nature of the jointing and other types of fracturing prevents prediction of well yields in bedrock except on a statistical basis.

Most previous studies of bedrock aquifers in Connecticut from the early investigation of Ellis (1909) to the present, concluded that water-yielding fractures diminish in both size and frequency with depth. The yields of wells open to equal thicknesses of saturated rock may vary considerably, but at a given site the yield should increase as a well is drilled deeper. However, the rate at which the yield increases should become progressively smaller.

The yield from any particular fracture increases until the pumping water level declines below its opening to the well and thereafter remains constant unless completely drained. For this reason, the specific capacity of a bedrock well generally varies as the water level is drawn down to different levels during pumping. Fractures in the upper part of the saturated zone may store small quantities of water but this usually becomes depleted a short time after pumping begins. In such cases, the well yield may noticeably decline with time.

The quantity of water that can be withdrawn from bedrock on a regional basis is governed by (1) the amount of recharge from precipitation, estimated to average from 8 to 10 inches per year (Mazzaferro and others, 1979), and (2) the ability of the aquifer to transmit water. Other factors that locally control well yields include presence or absence of saturated overburden (particularly stratified drift), lithology, depth to the top of the saturated zone, and details of well construction. To accurately determine the yield-depth relationships would require the testing of many wells at different depths as they are drilled or isolating zones with packers and testing each zone.

Sedimentary Bedrock

Sedimentary rocks underlie about 140 square miles of the Connecticut Valley lowland, as shown on plate C. Three extensive igneous layers (composed of basalt) are interbedded with four thick sedimentary units (composed dominantly of conglomerate, sandstone, and shale) as shown in the cross section on plate C. Faults are common in bedrock in the lowland and have caused the easterly dipping sedimentary and igneous strata to be repetitiously exposed. Furthermore, differential erosion has produced a distinct topography consisting of basalt ridges and valleys underlain by sedimentary rocks.

The sedimentary bedrock is apparently a better aquifer than the igneous and crystalline rocks, probably because of the additional open spaces along bedding planes and in intergranular pores. Bedding planes, common to all sedimentary rock, act like a horizontal set of joints, except that they continue throughout the unit. The joint sets, that commonly traverse or are perpendicular to the bedding planes may be 5 to 10 feet apart except near the land surface and faults.

Wells completed in sedimentary bedrock have a different distribution of yields than those tapping the other bedrock aquifers, as shown in figure 35. This figure shows the median yield of the sample of wells to be 10.8 gal/min for the sedimentary aquifer and that 95 percent yield at least 2.7 gal/min. These values are similar to those reported for 925 wells tapping sedimentary rocks in the adjacent Quinnipiac River basin (Mazzaferro and others, 1979) and indicate this aquifer is usually a reliable source of supply for domestic needs.

The distribution curve for well yields from sedimentary bedrock is higher and approximately parallel to those for igneous and crystalline bedrock aquifers. In most cases, wells are drilled to greater depths because high yields are required or inadequate water was obtained in the upper zones. The sedimentary rocks have some primary porosity that may vary with stratification but not with depth and it can be interpreted that the greater yields are a result of this primary porosity. However, the parallelism of the curves indicates that the main source of water is the same--from fractures and joints. It should also be noted that yield alone is not a reliable index of the ability of the bedrock aquifers in the basin to yield water, as it is directly related to the amount of drawdown. To evaluate well yield as a function of the thickness of saturated bedrock penetrated, 147 wells tapping sedimentary bedrock were divided into three classes on the basis of the amount of saturated uncased bedrock penetrated. The divisions are 50 to 100 feet, 100 to 200 feet, and more than 200 feet. The distribution of yields from each class is shown in figure 36.

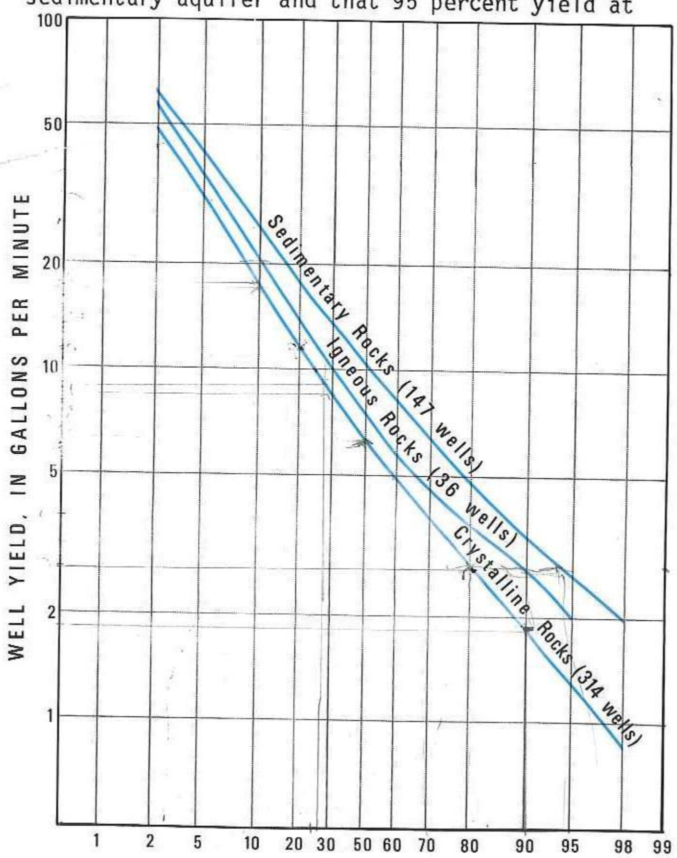


Figure 35.--Distribution of yields from wells tapping different bedrock aquifers in the study area

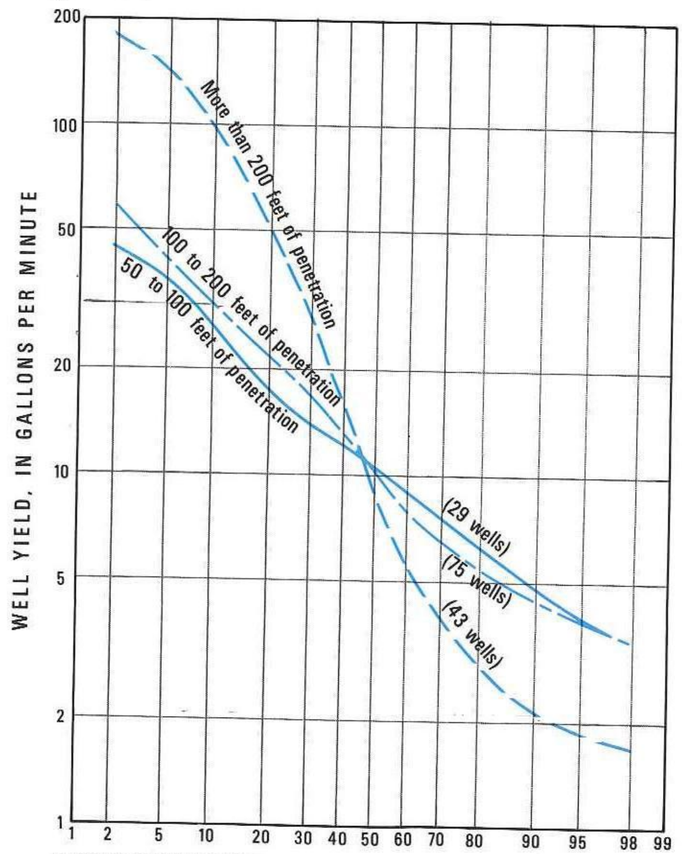


Figure 36.--Distribution of well yields according to thickness of uncased, saturated sedimentary rock penetrated

From this figure, it appears there is not a significant difference between median yields and that the distribution of yields is almost the same for the first two classes. Wells penetrating more than 200 feet of saturated uncased bedrock, however, are different in that this class has about half the wells with higher yields and half with lower yields than the others. This indicates 1) a much greater variation in the number of joints encountered and 2) that many of the joints die out below 200 feet of saturation.

The specific capacity per foot of uncased saturated bedrock penetrated is another useful index for comparison. Figure 37 shows the distribution, for the same three classes as in figure 36, of specific capacity per foot of uncased saturated bedrock penetrated. The median values for each class decrease significantly as the amount of penetration increases. For example, the median value for more than 200 feet of penetration (0.00029) is only about 13 percent of the median for the 50-100 feet class (0.0023). The curves of figure 37 indicate that the water-yielding joints and bedding planes in sedimentary bedrock diminish in size and frequency with depth and that, below 200 feet of saturated thickness, the specific capacity is dependent upon a more inconsistent factor, probably primary porosity.

In summary, the sedimentary-bedrock aquifer is capable of yielding on the average more water to an individual well than any other bedrock aquifer

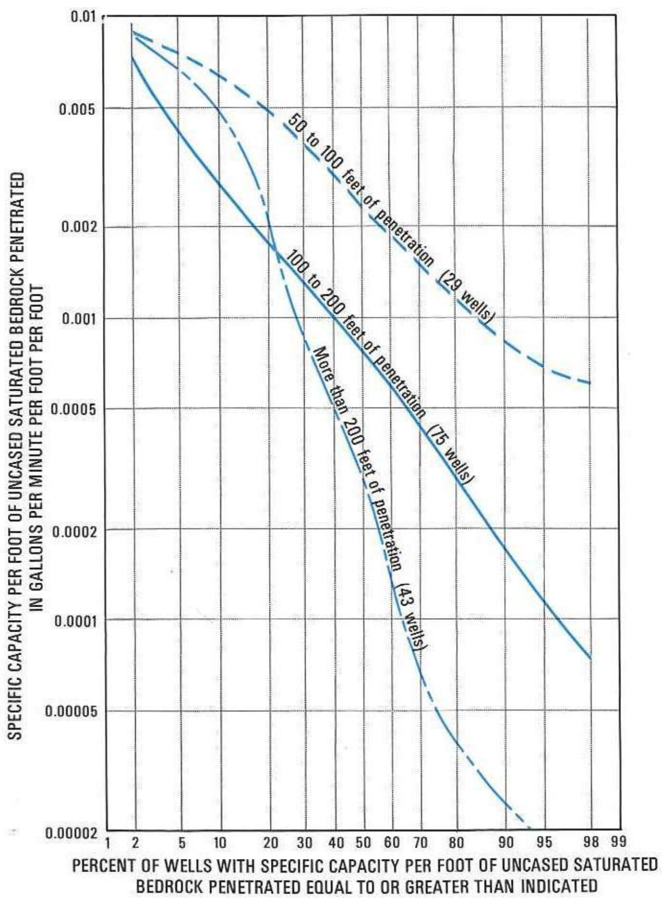


Figure 37.--Distribution of specific capacity per foot of uncased, saturated sedimentary bedrock

in the basin. About 95 percent of all wells tapping sedimentary bedrock yield at least 2.7 gal/min and 95 percent of those penetrating 200 feet or more of uncased saturated bedrock yield more than 1.9 gal/min.

Igneous and Crystalline Bedrock

Igneous and crystalline rocks in the basin are generally dense and hard and composed of tightly interlocking mineral grains. The most common types are basalt, granite, gneiss, and schist. The geologic and hydrologic characteristics are summarized in table 15. In some isolated areas, glaciation did not completely remove the weathered mantle of the bedrock and when drillers encounter this material, they commonly report "sand", "mica", or "soft rock".

The igneous-bedrock aquifer is restricted to basalt, which is interbedded with the sedimentary rocks. The basalt is a fine-grained, hard rock formed by solidification of lava flows. Many joints formed during the solidification process and these are also open spaces called vesicles near the top of the lava flow that originated as entrapped gas bubbles during cooling. Generally, the vesicles in the basalt are not abundant enough to be interconnected, except by joints and, therefore, do not affect the transmission of water through the rocks.

The igneous-bedrock aquifer is not tapped by a large number of wells. Curves in figure 35 show a median yield of about 8 gal/min, nearly the same as that reported for wells in the Quinnipiac basin (Mazzaferro and others, 1979). The curves (fig. 35) also indicate that igneous- and crystalline-bedrock aquifers are similar in their ability to yield water. More than 90 percent of the wells tapping igneous rocks yield more than 3 gal/min, and the wells provide domestic supplies at most sites.

As the igneous rocks are interbedded with the sedimentary rocks, it is not uncommon for a single well to tap both aquifers. At depth, the igneous rocks occur beneath a larger area than indicated by surface exposure. Wells that initially tap the sedimentary aquifer, but which are within about 1,500 feet and in a down-dip direction from igneous-rock outcrops, are most likely to encounter the igneous-bedrock aquifer at depths less than 375 feet.

The crystalline bedrock generally consists of metamorphic rocks that may be subdivided into two broad lithologic types, gneiss and schist. Gneiss is used in a broad context to include minor amounts of other coarse-grained rock types such as granite and pegmatite. It is characterized by relatively parallel orientation of mineral grains with massive to platy appearance. Schist is characterized by the predominance and parallel orientation of fine-grained mica and by the ease of separation into thin layers. These two rock types differ in their responses to tectonic stresses within the earth's crust. Gneissic rock types are more competent and respond to stresses by fracturing and formation of distinct open joints. Schist is less competent and responds by slipping and folding along foliation planes. Although joints develop in schist, they are likely to be small and discontinuous.

Most wells drilled into crystalline bedrock usually provide satisfactory supplies of good quality water (water-quality exceptions are noted in the discussion on pp. 52-53). The yield of a bedrock well cannot be predicted prior to drilling; nonetheless, a knowledge of factors influencing aquifer productivity can sometimes be utilized in selecting a site most likely to produce the largest yields. Some of the principal interrelated factors influencing well yield at a site are the number and width of joints, location and orientation of intersections of joint sets, and type and saturated thickness of overlying unconsolidated deposits.

The solid part of crystalline bedrock is essentially dense and impermeable, and water moves largely in joints or other types of fractures which are most common in the first 200 feet below the rock surface and become fewer and smaller in size with increasing depth. Parallel joints, forming a set, may intersect other sets, forming enlarged openings along which water moves more readily. Many joints are vertical or steeply dipping; others are roughly parallel to the bedrock surface. Although the orientation and spacing of joints are generally systematic in an area, the details of size and distribution are irregular and not predictable from existing information.

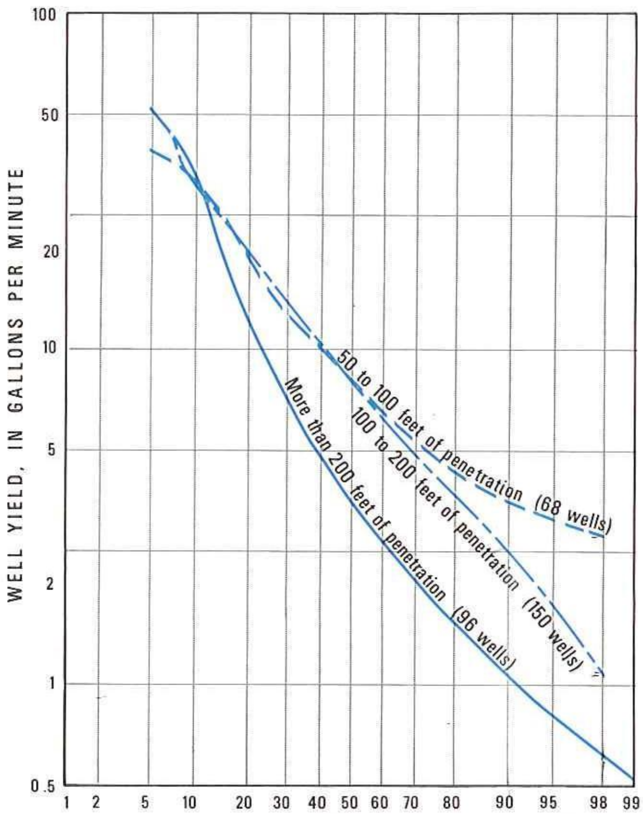


Figure 38.--Distribution of yields of wells penetrating different thicknesses of uncased-saturated crystalline rock

The crystalline-bedrock aquifer is the most widespread in the study area and is tapped by the most wells. The sample of 314 domestic wells tapping this aquifer have a median yield of 6.4 gal/min and 95 percent yield at least 1.3 gal/min (fig. 35).

Figure 38 shows the distribution of yields of the 314 crystalline bedrock wells subdivided into three classes on the basis of thickness of uncased saturated bedrock penetrated. The median yield is about 7.6 gal/min for the two classes penetrating less than 200 feet of saturated bedrock and about 3.4 gal/min for those penetrating more than 200 feet of uncased saturated rock. The curves in adequate yield after penetrating 200 feet of uncased saturated bedrock, the probability of increasing the yield by drilling deeper is small.

As stated previously, water-yielding fractures become less frequent and smaller with depth. Consequently, the yield of a well may increase as it is drilled deeper but at a decreasing rate.

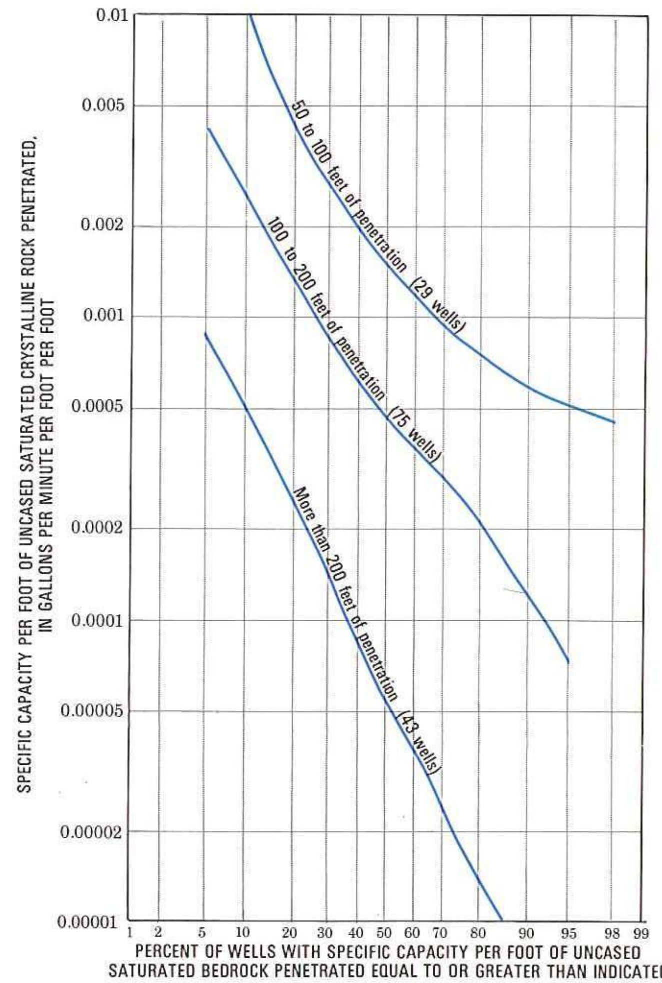


Figure 39.--Distribution of specific capacity per foot of uncased, saturated crystalline rock

It has been shown (fig. 38) that the median yield of wells tapping more than 200 feet of uncased saturated crystalline bedrock is significantly less than that of shallower wells. As with sedimentary rock, (fig. 37), the relationship of specific capacity per foot of uncased saturated crystalline bedrock penetrated, shown in figure 39, is more significant than yield alone. The figure shows that the specific capacities are consistently lower throughout the range of distributions as the penetration increases. The median specific capacity of wells tapping 50 to 100 feet of saturated crystalline bedrock is about 0.0014 gal/min/ft of drawdown per foot of uncased saturated crystalline rock penetrated. This is about 3 times the value for wells tapping 100 to 200 feet and about 27 times the value for those tapping more than 200 feet of uncased saturated bedrock. This statistical evidence strongly supports the conclusion that water-bearing openings in crystalline bedrock aquifers are more prevalent near the land surface and diminish with depth. Figure 39 also shows that only 4 percent of the wells penetrating more than 200 feet of saturated rock have specific capacities greater than the median value for wells tapping 50 to 100 feet.

Methods of Drilling

In recent years, air-percussion rotary-drill rigs have been used extensively to complete 6- and 8-inch diameter bedrock wells. These drill rigs use compressed air to drive a down-the-hole hammer bit and to blow the cuttings and water out of the hole. They drill rapidly and leave a clean hole, although it is possible for some of the cuttings to enter joints and partially plug them when air pressure from the bit is greater than hydraulic pressure in the joint.

An older but still popular drilling method is the cable-tool rig (pounder). This type of drill rig is more commonly used for largediameter wells (10 inches or greater) in stratified drift where a screen has to be set near the bottom of the well. In bedrock, the drilling speed is relatively slow but usually does not plug up the joints unless the driller lets the cuttings accummulate into a thick mud before bailing. The process of scrubbing the uncased bedrock portion of a hole to dislodge any scale and cuttings that may plug the pores or joints is easy with this type of rig.

A "dry hole", while uncommon, can be drilled by any type of rig and in most any area, because of the random chance of not penetrating any water-bearing fractures. Before abandoning a dry hole, one method that can be tried is to set off an explosive charge at one or several depths in an attempt to create some cracks to interconnect the well and nearby joints. This approach is not used very frequently in New England but is common in some other parts of the country.

QUALITY OF WATER

As water circulates throughout the hydrologic cycle, its quality changes. In the atmosphere, water vapor dissolves dust, gases, and ocean-borne salts and carries them to the land surface. Here, some of it runs off into streams, picking up additional solids and, as it percolates into the ground, it is in close contact with soils and rocks for extended periods, dissolving their constituents and discharging them to streams. Water in streams and aquifers may also be affected by man, and only by proper sampling procedures can the natural and man-made quality conditions be separated and compared. Analyses of 249 samples collected in the study area--from precipitation, surfacewater and ground-water sites (pl. A)--form the basis for the following discussion.

PRECIPITATION

The medians and ranges of 25 analyses of water from 3 precipitation gages, showing constituent concentration and the calculated load per square mile per month falling on the basin, are given in table 21. During the period April 1 - December 1, 1971, a mean monthly dissolved-solids load of 6.4 tons per square mile fell on the basin. The major dissolved chemical constituents were chloride, sulfate, sodium, and nitrogen. A plot of the monthly cumulative constituent loads (fig. 40) shows that sodium, chloride, sulfate, and combined calcium and magnesium increased markedly in August 1971, while bicarbonate and

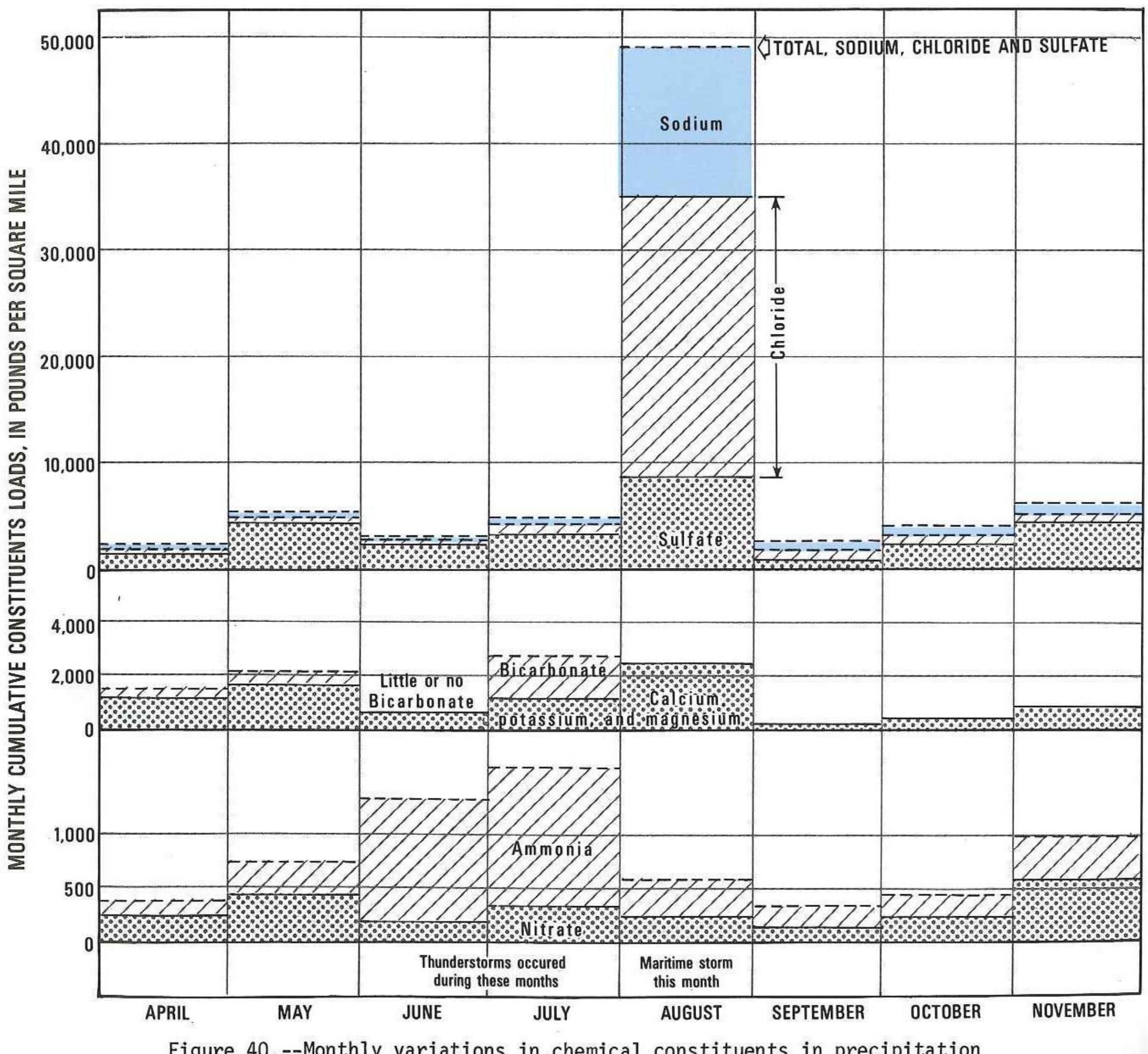


Figure 40.--Monthly variations in chemical constituents in precipitation from April 1 to December 1, 1971

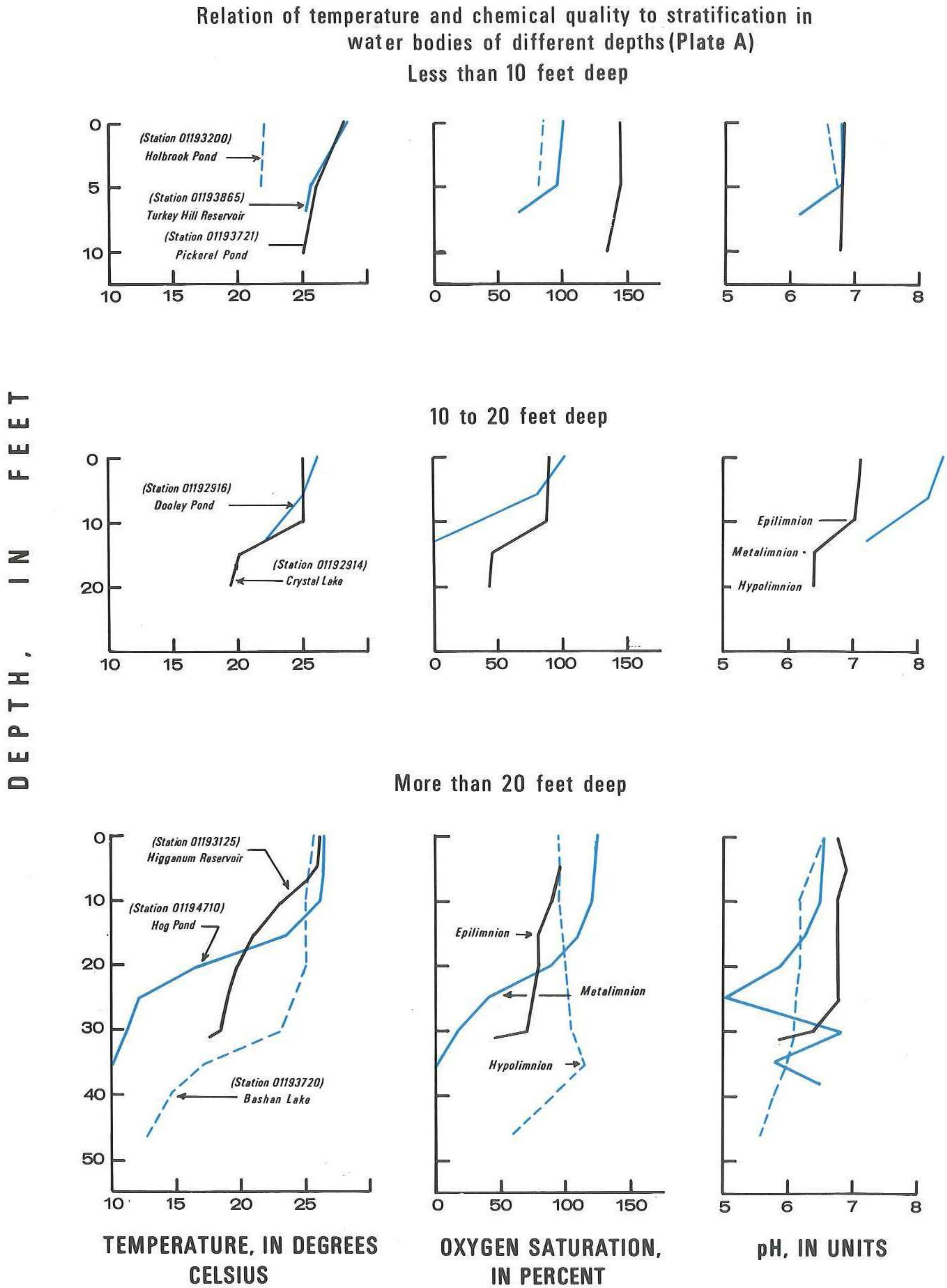


Figure 41.--Chemical and physical characteristics of water in shallow, intermediate, and deep lakes during 1954

nitrogen decreased. This was the result of a maritime storm which carried many ocean-borne salts inland. Sulfate loads were consistently large and, except in August, probably resulted from the solution of sulfurous oxide gases in water vapor to form sulfate. The nitrogen loads probably were caused in large part by nitrous oxide gases that formed nitrate nitrogen and ammonia nitrogen. The ammonia and nitrate (fig. 40) concentrations increased markedly during thunderstorms such as those of June and July 1971. The data indicate that a small but significant part of the constituents in water circulating in the basin come from precipitation.

Table 21.--Chemical and physical quality of precipitation[1/]

[Chemical and physical quality of water from three precipitation gages (shown on pl. A) for the period April 1 to December 1, 1971 and calculated distribution of dissolved constituents]

Constituent or property	Dissolved constituents in milligrams per liter except as noted: Median[2/]	Range	Load of solids dissolved in rainfall on the basin (in tons per square mile per month) [4/]: Mean[2/]	Range
Silica (SiO_2)	0.1	0.0 - 0.2	0.017	0.004 - 0.032
Calcium (Ca)	.5	.0 - 3.5	.266	.033 - .610
Magnesium (Mg)	.1	.01- 7.0	.123	.004 - .735
Sodium (Na)	.7	.3 - 70	1.125	.064 - 7.150
Potassium (K)	.5	.0 - 2.3	.166	.071 - .426
Bicarbonate (HCO_3)	.0	.0 - 3.0	.154	0 - .830
Sulfate (SO_4)	5.0	.9 - 22	1.655	.441 - 2.850
Chloride (Cl)	1.0	.3 - 130	1.915	.131 13.250
Fluoride (F)	[3/] .0	[3/].0 - .2	.001	0 - .008
Nitrate as Nitrogen (NO_3 as N)	.5	.0 - 1.4	.149	.009 - .200
Ammonia, nitrite, and nitrate ($NH_3 + NO_2 + NO_3$ as Nitrogen)	[3/]1.2	[3/].2 - 13	.385	.192 - .665
Dissolved solids (sum)	12	3.0 - 236	6.420	1.730 25.950
Hardness as $CaCO_3$ (calcium, magnesium)	2	0 - 38	-	- -
Noncarbonate hardness as $CaCO_3$	2	0 - 38	-	- -
Specific conductance (micromhos at 25°C)	35	15 - 491	-	- -
pH	4.5	3.8 - 5.8	-	- -

1/ Based on a total of 25 analyses resulting from a single analysis of cumulative monthly rainfall from each of the three stations for a period of about 9 months.
2/ Computed by Thiesson distribution of mean monthly precipitation multiplied by mean monthly chemical concentration at the three precipitation sites.
3/ Based on 19 samples.
4/ Weighted.

LAKES, PONDS, AND RESERVOIRS

Part of the precipitation falling on the land surface flows to natural or man-made lakes, ponds, and reservoirs. Man-made impoundments may be used for water supply, irrigation, hydroelectric generation, recreation, and flood control. Lakes, ponds, and reservoirs are usually quiescent and, even when water is flowing, its velocity is low. These characteristics can influence the water quality, such as dissolved oxygen.

Thermal stratification (Hutchinson, 1957) refers to the conditions where layers or strata of water with different temperatures exist in a quiet body of water, and it can indirectly affect the quality of water in lakes, ponds, and reservoirs. During the spring and fall months, enhanced circulation and mixing cause these water bodies to have uniform temperature from top to bottom. In the winter, however, circulation is inhibited, and temperatures at the surface are colder than those at the bottom. Stratification is also prominent in the summer when water at the surface is warmer than at the bottom. The deeper the water body and the more protected from strong winds that cause mixing, the greater the likelihood of stratification. Figure 41 relates stratification to the depths of typical bodies of quiet water in the study area. In water bodies less than 10 feet deep, the maximum temperature variation with depth was 3°Celsius (C). Water temperatures in lakes 10 to 20 feet deep varied as much as 5.5°C and those in lakes deeper than 20 feet varied as much as 15.5°C. The water bodies of medium and great depth show three clearly defined layers: an upper layer with warm temperature (epilimnion), a middle layer with pronounced temperature changes (metalimnion), and a lower layer with cold temperatures (hypolimnion). The plane or planes of most rapid temperature change are referred to as the thermocline.

Thermal stratification affects color and turbidity, which in turn inhibits light penetration and affects the chemical quality of the water. As shown in figure 41 for Dooley and Hog Ponds, oxygen below the epilimnion decreased rapidly to zero. Water bodies with low dissolved-oxygen concentrations are environments for reduction of chemical constituents back into solution (Hutchinson,

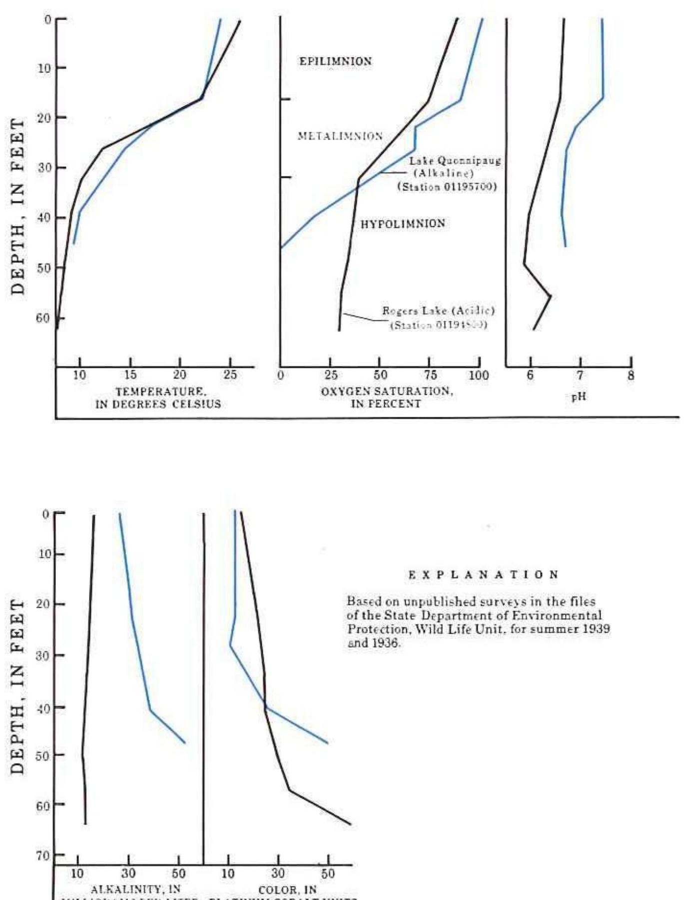


Figure 42.--Comparison of alkaline and acidic lakes in the study area

1957, p. 695). Figure 42 shows that in two other lakes (Rogers and Quonnipaug) the epilimnion, or upper 10 feet, was nearly super-saturated with oxygen in the summers of 1936 and 1939. Lake Quonnipaug is alkaline and Rogers Lake is acidic, but both lakes are stratified (Connecticut Board of Fisheries and Game, 1959) and appear to have had photosynthesis occurring in their epilimnion. Oxygen concentration in Lake Quonnipaug decreased to zero at a depth of 47 feet. Both lakes became more acidic with depth, probably owing to gases given off by organic decomposition which formed carbonic acid (H_2CO_3). In Rogers Lake, alkalinity was fairly uniform from top to bottom but in Lake Quonnipaug, it increased markedly with depth. This was probably caused by carbon dioxide, resulting from plant respiration or from oxidizing organic matter forming bicarbonate alkalinity. Recent investigations of the water quality of Rogers Lake, Lake Beseck, Lake Terramuggus, and Lake Pocotopaug are discussed by Norvell (1975).

STREAMS, ESTUARIES, AND AQUIFERS

The quality of water in streams results from the combined natural quality of precipitation, overland runoff, and ground-water runoff, and of superimposed man-induced effects. During periods of high flow, all of these contributions are important, but during low flow streams are affected mostly by ground-water runoff and man-made conditions. By observation and by analysis of ground-water quality in relation to that of surface water, man-made conditions can sometimes be isolated from natural conditions.

A reconnaissance survey of dissolved-solids concentrations was made when the streamflow was about 80-percent duration and aquifers were subsequently sampled at numerous sites (fig. 43). Streamflow and water from wells tapping aquifers in sedimentary bedrock had dissolved solids generally greater than or equal to 200 milligrams per liter (mg/L) west of the Eastern Border Fault (fig. 43). Dissolved-solids concentrations east and south of the fault were generally less than 200 mg/L. Estuaries containing saline water from Long Island Sound (fig. 43) had dissolved-solids concentrations in excess of 500 mg/L. Some streams in the northwestern part of the area also had dissolved solids exceeding 500 mg/L as a result of man-induced conditions (fig. 43). Dissolved-solids concentrations in streams and aquifers in the northwestern part are generally 100 to 300 mg/L and reflect, in part, the dissolved minerals in sedimentary rock and man-made conditions. The dissolved-solids concentrations for the remainder of the area are generally less than 100 mg/L, reflecting the low solubility of crystalline rocks. Saline water in most of the streams rarely moves further north than latitude 41°18'30", except in the Connecticut River, where it occurs as far north as East Haddam.

NATURAL CONDITIONS

Dissolved Solids

A total of 52 samples from 26 surface-water sites and 128 samples from different wells were analyzed for chemical and physical constituents (Sites on plate A). These samples were collected where the water quality is most likely to reflect natural conditions. The medians and ranges in concentration of various chemical constituents and physical properties are summarized in table 22.

The dissolved-solids concentration in water from 26 streams sampled during high flow (10-percent duration) had a median value of 42 mg/L and a range of 23 to 152 mg/L. In contrast, water from the same streams sampled during low flow (90-percent duration) had a median concentration of 61 mg/L and a range of 25 to 288 mg/L. The greater concentrations occurring during low flow are representative of the ground-water runoff from unconsolidated and consolidated aquifers in the basin (table 22). Only water from wells tapping sedimentary and igneous rocks exceeded the limit of 500 mg/L established by the Connecticut General Assembly (1975) for drinking water.

Iron and Manganese

Iron and manganese are minor dissolved constituents in water and are similar in chemical behavior. They are derived from the solution of minerals and from organic matter (Hem, 1970). Of 26 stream samples collected during periods of high flow, 9 had iron or manganese concentrations equal to or greater than the suggested limits for drinking water of 1.0 mg/L and 0.05 mg/L, respectively established by the Connecticut General Assembly (1975). In contrast, during low flow, 17 of 26 samples from the same sites had concentrations exceeding these limits. The median concentrations of iron and manganese were 0.27 and 0.00 mg/L during high flow and 0.22 and 0.05 mg/L during low flow, respectively.

Of 128 samples of water from wells tapping unconsolidated stratified-drift deposits and bedrock in the basin, 58 had iron or manganese concentrations equal to or greater than the recommended limits (fig. 45). High concentrations of iron and manganese in water from coarse-grained stratified drift are common near the Connecticut River. These concentrations probably result from the solution of iron minerals in waters that have little or no dissolved oxygen. Such reducing conditions are possible where coarse-grained deposits underlie thick, fine-grained material. The percent chance of occurrence of daily ground-water pumpage and concentrations of iron and manganese is shown in figure 44. The pumpage was from the coarse-grained stratified-drift aquifer tapped by wells of the Middletown Water Department, during the period 1968-71. The increase in iron and manganese concentrations with increased pumpage is

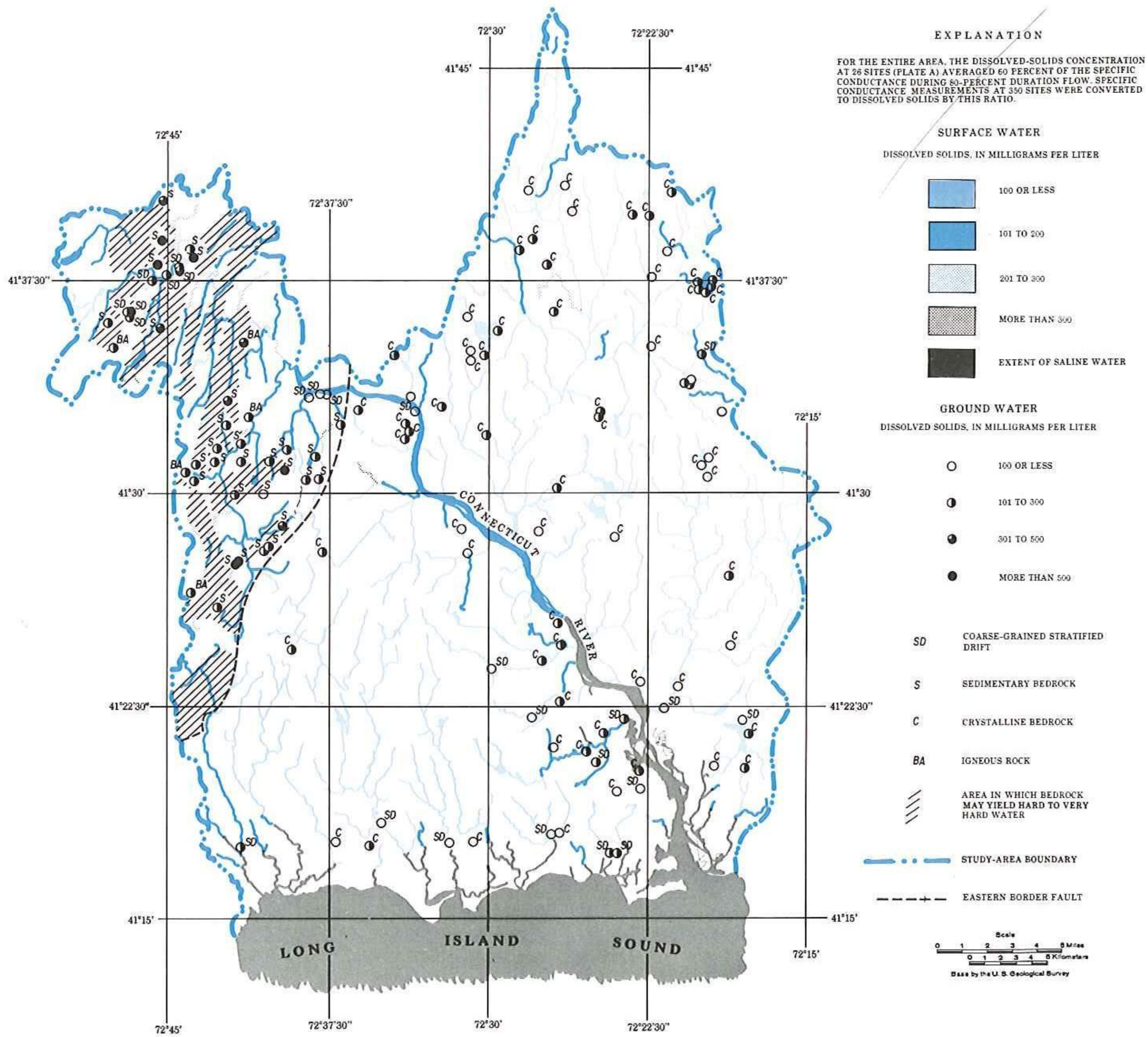


Figure 43.—Maximum observed concentrations of dissolved solids in surface and ground waters

Table 22.--Summary of quality of water from streams and aquifers

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

Constituent or property	Streams under natural conditions: High flow (10-percent flow duration) 1/ Median	High flow Range	Low flow (90-percent flow duration) 1/ Median	Low flow Range	Aquifers: Stratified drift (coarse-grained) Median	Stratified drift Range	Stratified drift No. of wells sampled for each constituent 2/	Sedimentary bedrock Median	Sedimentary bedrock Range	Sedimentary bedrock No. of wells sampled for each constituent 2/	Crystalline bedrock Median	Crystalline bedrock Range	Crystalline bedrock No. of wells sampled for each constituent 2/	Recommended maximum limit for drinking water 3/
Silica (SiO_2)	5.6	2.1 - 8.6	8.4	1.3 - 14	11	3.1 - 30	23	15	9.4 - 26	30	18	8.1 - 28	37	-
Iron (Fe)	.27	.07 - .72	.22	.06 - 2.0	.2	.0 - 40	37	.14	.04- .60	30	.17	.04 - 5.2	61	-
Manganese (Mn)	.00	.00 - .10	.05	.00 - .15	.07	.00 - .65	33	.01	.00- .24	30	.03	.00 - .58	56	-
Calcium (Ca)	5.0	2.5 - 28	7.4	2.9 - 56	14	5.4 - 75	24	40	6.0 - 540	30	23	4.0 - 66	36	-
Magnesium (Mg)	1.4	.6 - 7.0	1.8	.9 - 14	3.5	.7 - 30	24	12	1.5 - 42	30	2.8	.9 - 15	36	-
Sodium (Na)	4.6	2.2 - 18	6.6	3.7 - 32	8.7	3.3 - 58	23	20	4.8 - 410	30	8.4	2.7 - 40	37	4/ 20
Potassium (K)	.7	.4 - 1.3	1.2	.6 - 2.5	1.4	.4 - 4.1	23	1.0	.4 - 6.4	30	2.6	.0 - 5.3	36	-
Bicarbonate (HCO_3)	10	3 - 79	20	8 - 174	34	9 - 305	36	134	18 - 470	30	62	4 - 205	41	-
Sulfate (SO_4)	12	3.5 - 30	12	6.5 - 47	20	2.6 - 63	32	40	15 1,600	30	15	4.1 - 46	36	-
Chloride (Cl)	7.8	3.3 - 5/ 37	8.9	4.3 - 5/ 57	14	2.2 - 250	36	10	1.3 - 260	30	6.5	.4 - 140	41	250
Fluoride (F)	-	- -	.1	.0 - .2	.0	.0 - .1	22	.3	.0 - 6.1	30	.1	.0 - .6	37	2.0
Nitrate (NO_3)	.3	.0 - 3.7	.9	.0 - 7.1	3.5	.0 - 29	36	4.0	.0 - 84	30	.2	.0 - 16	59	6/ 10
Phosphate (PO_4)	.04	.02 - .22	.03	.0 - .46	-	- -	-	-	-	-	-	-	-	-
Dissolved solids (sum)	42	23 - 150	61	25 - 288	116	44 - 416	32	231	96 - 2,400	30	116	31 - 286	37	500
Hardness (as $CaCO_3$)	18	9 - 97	27	11 - 197	73	16 - 310	33	156	22 - 1,520	30	68	14 - 186	42	-
Noncarbonate hardness (as $CaCO_3$)	12	6 - 44	10	4 - 63	28	1 - 76	35	36	0 - 1,450	30	15	0 - 130	41	-
Specific conductance (micromhos at 25°C)	68	39 - 278	98	45 - 511	154	67 - 458	22	404	163 - 2,650	30	184	39 - 557	50	-
pH (units)	6.7	5.2 - 8.2	6.9	6.0 - 8.1	7.1	6.2 - 8.4	38	7.6	6.7 - 8.7	30	7.7	5.7 - 8.2	43	-
Color (platinum-cobalt units)	18	3 - 75	8	2 - 110	-	- -	-	-	-	-	-	-	-	9/ 20-250
Turbidity (JTU) 7/	1	0 - 7	1	0 - 8/ 10	-	- -	-	-	-	-	-	-	-	-
(mg/L of SiO_2)	-	- -	3	1.5 - 8/ 15	-	- -	-	-	-	-	-	-	-	-

1/ Flow duration computed by comparison of unit runoff with records at 26 continuous stream-gaging sites where one sample at each site was collected during high and low flow. Computed for base period 1931-60, by method shown in figure 5.
2/ One analysis per well.
3/ Recommended by Connecticut General Assembly (1975).
4/ Finished treated water.
5/ Affected by man.
6/ Nitrite and nitrate as nitrogen.
7/ Turbidity determined by two methods, one reported in Jackson turbidity units (JTU) and the other in milligrams per liter of silica.
8/ Based on type of treatment.
9/ Based on 25 samples.

graphically represented in figure 44. During pumping, water infiltrates from the Connecticut River which, during low and moderate flows, has iron and manganese concentrations below 0.3 and 0.05 mg/L, respectively. The data indicates that 1968 concentrations in the aquifer before pumping were higher than those in the river, and that the concentrations of the two constituents increased as pumpage increased. Both constituents probably are readily available in the oxidized state in the riverbed sediments or aquifer materials. As pumpage increased, a cone of depression developed and expanded, enlarging the area of river water

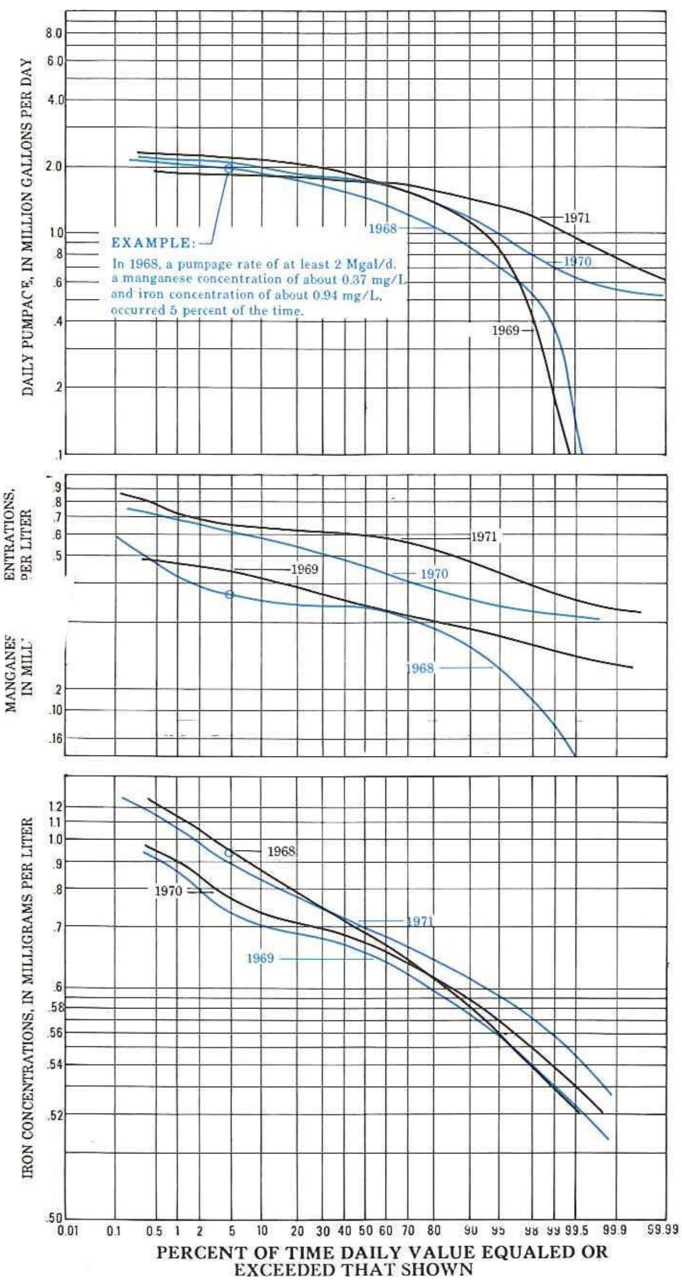


Figure 44.--Relation between daily duration of well pumpage and concentrations of iron and manganese in water from the Middletown well field during 1968-71

infiltration and thereby drawing more of these constituents toward the well field. In the absence of oxygen, the constituents were presumably dissolved in the water as it passed downward through the reducing environment associated with the fine-grained deposits.

The areal distribution of iron or manganese in surface and ground waters is shown in figure 45, as are areas where high concentrations are common. Water from the crystalline rocks, that are widespread in the basin, is generally high in iron and manganese. The type of rock believed to be the major source is a rusty weathered schist that occurs chiefly east of the Connecticut River (pl. C).

Hardness

Hardness in water is determined largely by compounds of calcium and magnesium and is expressed in terms of calcium carbonate ($CaCO_3$). Hardness caused by carbonate is referred to commonly as "temporary" hardness and that caused by sulfate or chloride is called "permanent" hardness. The classification used in this report is based on that of the U.S. Geological Survey, as follows:

Range of hardness as $CaCO_3$ (in mg/L)	Classification	Suitability and treatment1/
0- 60	Soft	Suitable for most purposes without softening.
61-120	Moderately hard	Usable without treatment except in some industrial applications.
121-180	Hard	Softening required for laundries, some industries, and most domestic uses.
Greater than 180	Very hard	Softening required for almost all uses.

1/ Methods of softening water are discussed in a report by Wilke and Hutchinson (1962).

The hardness of water from samples in the study area is given in table 22. The median hardness at 26 surface-water sites (1 sample per site) during high flow was 18 mg/L, contrasted to 27 mg/L during low flow. The higher median concentration during low flow reflects in part the greater influence of ground-water runoff. The median hardness of water from 33 wells (1 analysis per well) tapping coarse-grained stratified-drift deposits and from 42 wells tapping crystalline bedrock was 73 and 68 mg/L, respectively. By contrast, the median value from 30 wells tapping sedimentary rock was 156 mg/L. Surface water during periods of low flow will probably have greater hardness in areas underlain by sedimentary bedrock than in areas underlain by coarse-grained

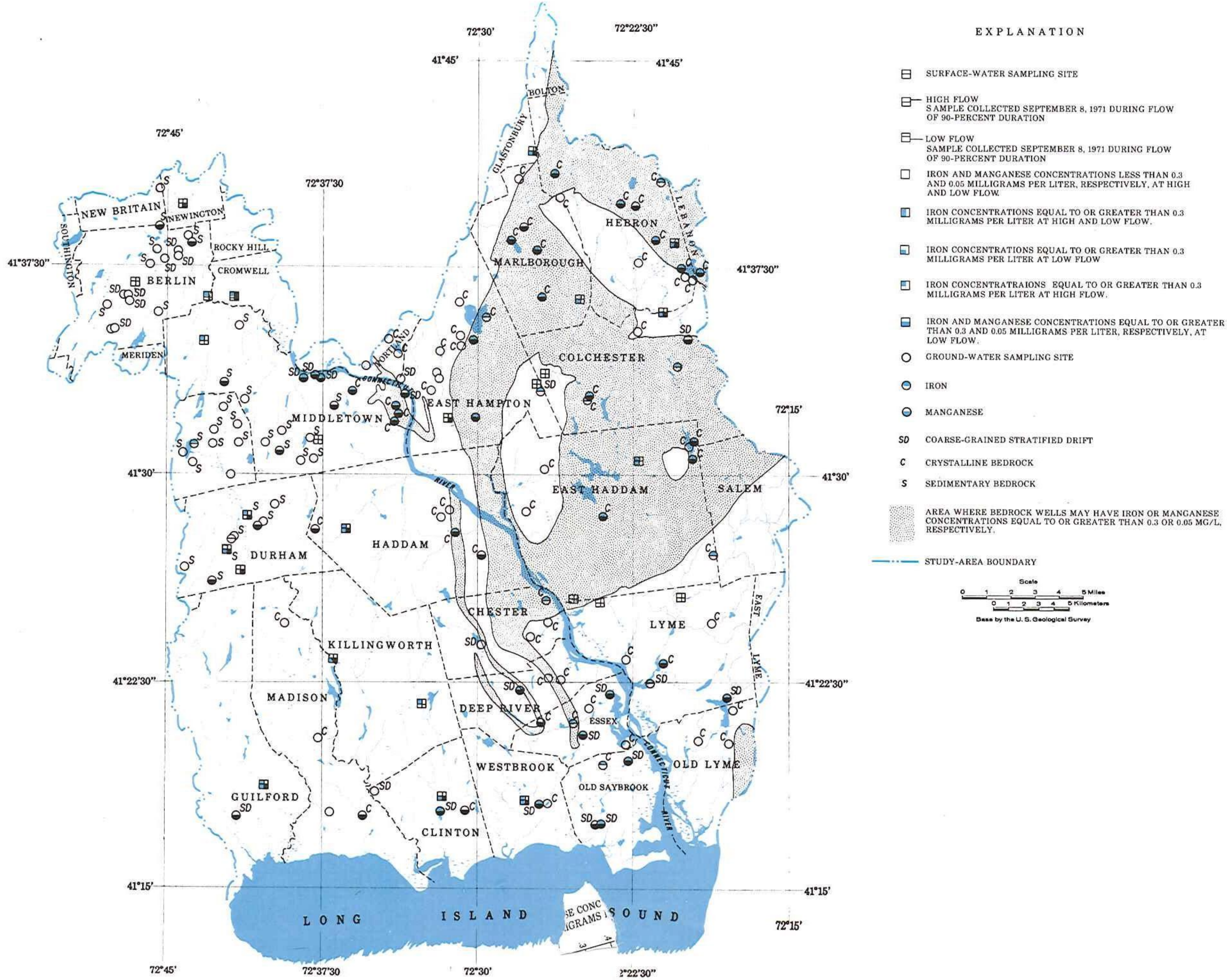


Figure 45.—Areal distribution of i and manganese in surface and ground waters

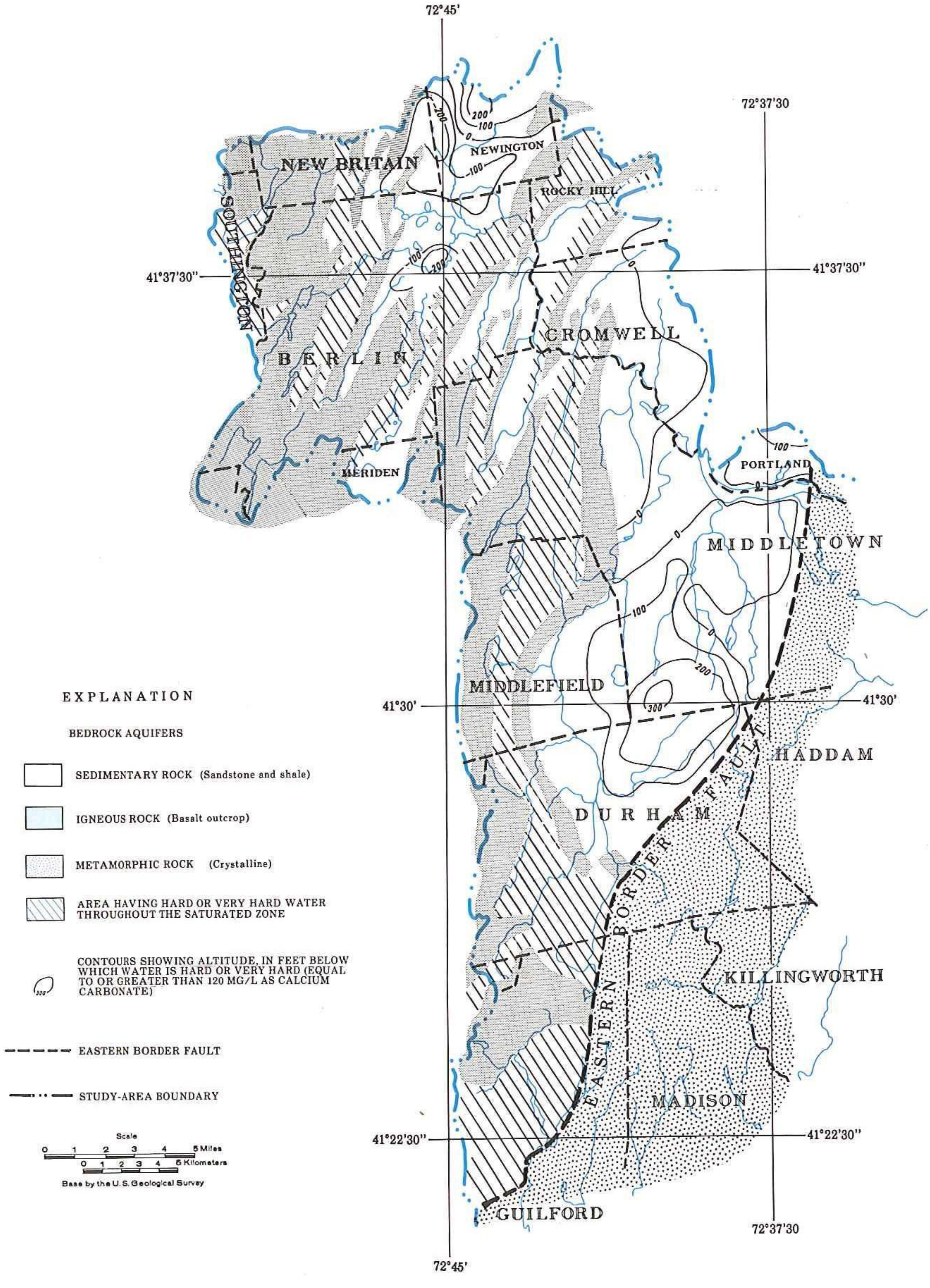


Figure 46.--Areal distribution of hard water in the sedimentary rocks

stratified-drift deposits and crystalline bedrock (Mazzaferro and others, 1979, table 17).

Figure 46 shows the areal distribution of hard and very hard water in the sedimentary rocks that are all in the western part of the basin. The figure shows that some areas, predominantly underlain by shale, have hard or very hard ground water throughout the saturated zone. The hardness in these areas may be caused by the dissolution of compounds of calcium and magnesium carbonate. In areas underlain by sandstone, the contours on figure 46 indicate the altitude below which the hardness of the ground water is likely to be equal to or greater than 120 mg/L. The hardness in these areas is caused mainly by the dissolved constituents of calcium or magnesium sulfate, as opposed to carbonates, when the dissolved-solids concentrations are greater than 300 mg/L (Ryder and others, 1981).

Nitrates and Phosphates

Nitrates are naturally produced by the oxidation of nitrogen in air by bacteria, and by the decomposition of organic material in soil (Hem, 1970, p. 181). Fertilizers may add nitrate and phos-phate directly to water, commonly with nitrate concentrations 10 times that of phosphate (Federal Water Pollution Control Administration, 1968).

Most of the farming and urbanization is in the northwest, within the Mattabesset River basin, that comprises 17 percent of the study area. Table 23 lists nitrate loads during high flow, and phosphate loads during low flow in the Mattabesset River basin and in the remainder of the area. The mean loads shown in the table indicate that, with the exception of the Mattabesset River basin, the water generally has low concentrations of nitrate and phosphate, indicating relatively little effect from fertilizers.

Table 23.--Comparison of the nitrate and phosphate loads in the Mattabesset River basin and in the remainder of the study area

(In pounds per square mile per day)

	Mattabesset River basin					Remainder of the study area				
Constituent	Mean	Range	Date	Flow duration 1/ (percent)	No. of samples	Mean	Range	Date	Flow duration 1/ (percent)	No. of samples
Nitrate load	35	0.0 - 92.5	5-14-71	5	9	7.1	0.0 - 22	5-14-71	5	9
Phosphate load	2.8	0.6 - 5.4	9-8-71	90	17	1.1	0.1 - 3.8	9-8-71	90	17

1/ Flow duration is based on comparison of unit runoff at 35 continuous-recording stream-gaging sites for base period 1931-60, by method shown in figures 9 and 15.

Sediment

Suspended sediment consists of various amounts of sand, silt, and clay carried in suspension after being eroded from stream banks and channels or carried into streams by overland runoff. Nineteen suspended-sediment samples were collected during periods of high and low flows from 13 sites on both estuarine and non-estuarine reaches of 7 streams (table 24). Analysis of the few samples from the upper, non-tidal reaches collected during low flow on October 5 and 6, 1971, indicates that during a period of no overland runoff all fresh-water sediment loads were zero, whereas, during the same period in the tidal reaches of the same streams, the loads ranged from 1.4 to 5,340 tons per day. Presumably, the estuarine loads came from Long Island Sound. The ranges in sediment loads and directions of flow during October 5 and 6, 1971, are shown in figure 47.

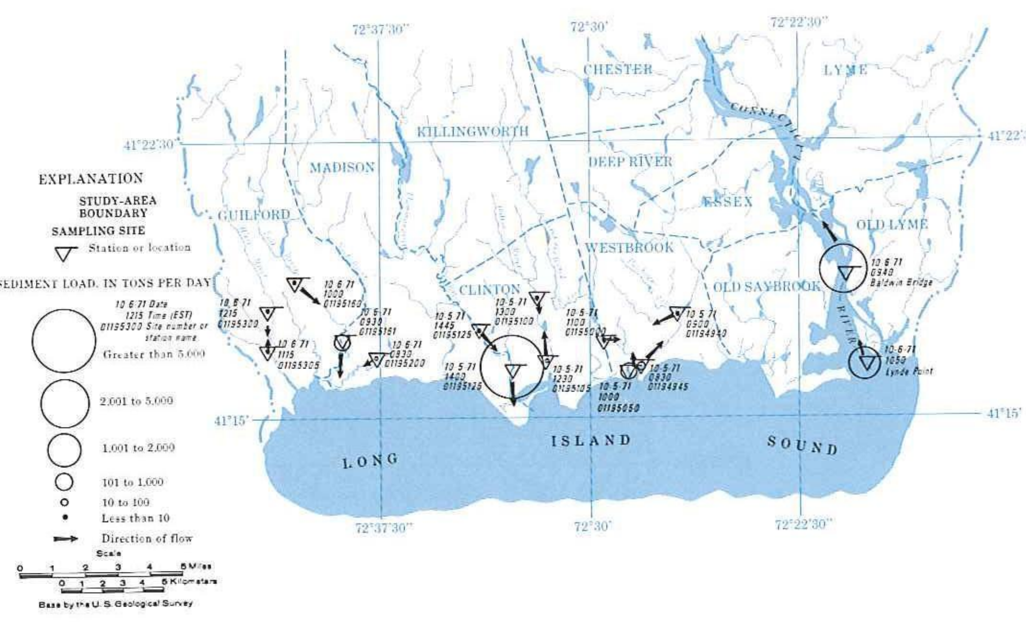


Figure 47.--Distribution of suspended-sediment load due to tidal inflow in estuarine reaches of streams on October 5-6, 1971

Samples of water from the Connecticut River at selected sites in the tidal reach were analyzed for suspended sediment as well as other physical and chemical constituents. These samples were collected on October 6, 1971, and June 23, 1972, by personnel of the University of Connecticut Marine Laboratory at Noank. Figure 48 shows that at Baldwin Bridge, (See pl. A) salinity, recorded as specific conductance, is variable with depth during low fresh-water flow and upstream tidal flow. Measurements show a pronounced stratification, with lower values of dissolved-solids and suspended-sediment concentrations near the water surface than near the river bottom. At Lynde Point, 3.4 miles downstream from the bridge, the difference between the dissolved-solids concentration at the water surface and near the river bottom disappeared, and the difference between the suspended-sediment concentrations at the water surface and near the river bottom became small. During high freshwater inflow on June 23, 1972 (fig. 49), the stratifications were much higher, and there was an increased contrast between sediment concentrations in the upper layer and the lower layer. Only small differences in the 5-day biochemical oxygen demand and dissolved oxygen at 20°C between high and low tide were measured. Additional chemical data collected on the river from 1970 to 1972 are contained in a report by Gallagher and Bohlen (1972).

Table 24.--Physical quality of water in estuarine reaches of selected streams

Station No. (pl. A)	Station and location	In autumn (October 5, 6, 1971) Instantaneous discharge (ft^3/s)	Instantaneous discharge direction1/	Suspended sediment (mg/L)	Suspended sediment (tons/day)	Specific conductance in micromhos at 25°C	Turbidity (JTU)2/	Water temperature (°C)	In spring (June 23, 1972) Instantaneous discharge (ft^3/s)	Instantaneous discharge direction1/	Suspended sediment (mg/L)	Suspended sediment (tons/day)	Specific conductance in micromhos at 25°C	Turbidity (JTU)2/	Water temperature (°C)
01194940	Patchogue River at Westbrook	0.42	down-stream	12	0.0	154	1	18.0	-	-	-	-	-	-	-
01194945	Patchogue River at Grove Beach	150	up-stream	34	14	30,000	1	18.0	187	upstream	33	17	5,800	5	16.5
01195000	Menunketesuck River near Clinton	.52	down-stream	.8	0	104	0	17.0	-	-	-	-	-	-	-
01195050	Menunketesuck River at Grove Beach	2,000	up-stream	40	216	38,000	0	19.0	2,220	downstream	18	108	10,500	5	17.0
01195100	Indian River near Clinton	.32	down-stream	1.3	0	109	4	18.5	-	-	-	-	-	-	-
01195105	Indian River at Clinton	200	up-stream	13	7.0	38,000	0	20.0	374	downstream	11	11	2,100	5	16.5
01195125	Hammonasset River near Clinton	30.5	down-stream	17	1.4	3,250	1	18.0	-	-	-	-	-	-	-
01195126	Hammonasset River near Clinton	2,500	down-stream	791	5,340	30,000	0	20.0	1,760	downstream	87	413	142	5	17.0
01195200	Neck River near Madison	.44	down-stream	0	0	146	1	19.0	150	downstream	6	2.4	86	2	17.0
01195160	East River near Guilford	2.6	down-stream	4.4	0	77	1	18.5	-	-	-	-	-	-	-
01195161	East River near Guilford	1,300	up-stream	36	197	19,000	0	19.5	933	downstream	17	43	600	5	18.0
01195300	West River near Guilford	4.7	down-stream	2.9	0	160	1	16.5	-	-	-	-	-	-	-
01195305	West River at Guilford	0	-	20	0	2,040	1	18.0	-	downstream	-	-	116	4	17.0

1/ Direction downstream indicates streamflow during outgoing tide; upstream indicates flow during incoming tide.
2/ Jackson turbidity units.

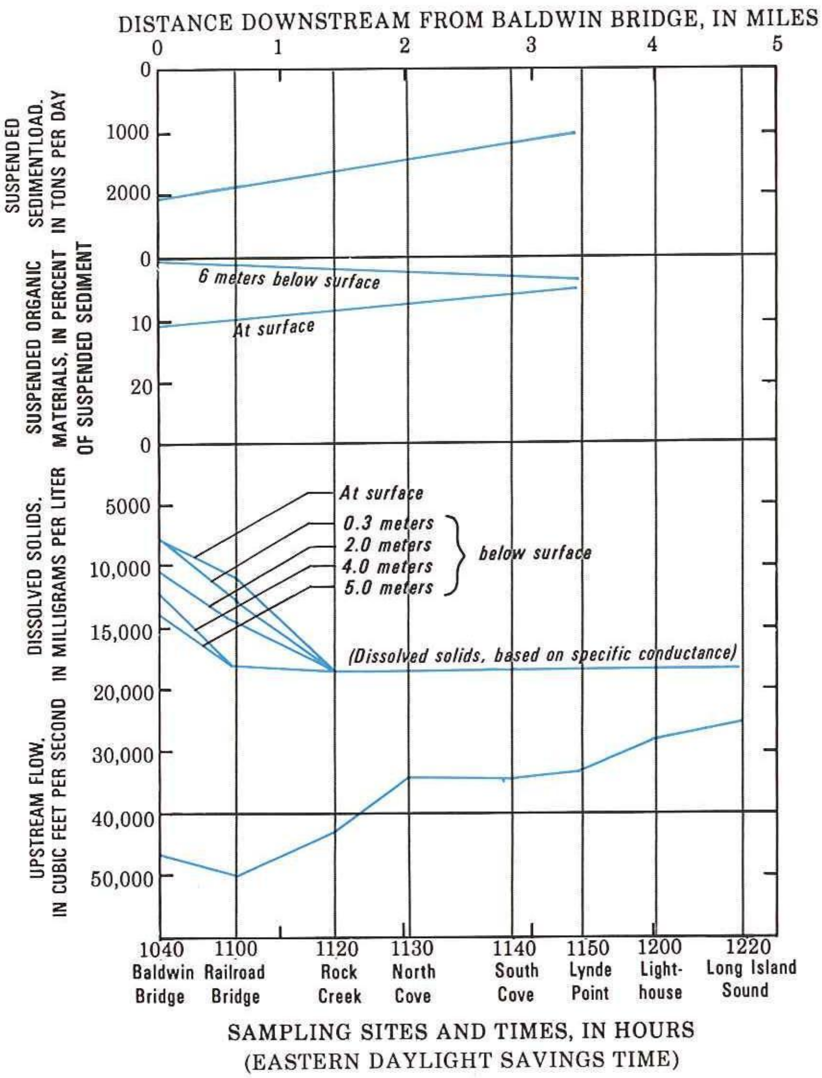


Figure 48.--Downstream changes in streamflow, suspended organic material, suspended-sediment load, and dissolved-solids concentration near the mouth of the Connecticut River on October 7, 1971

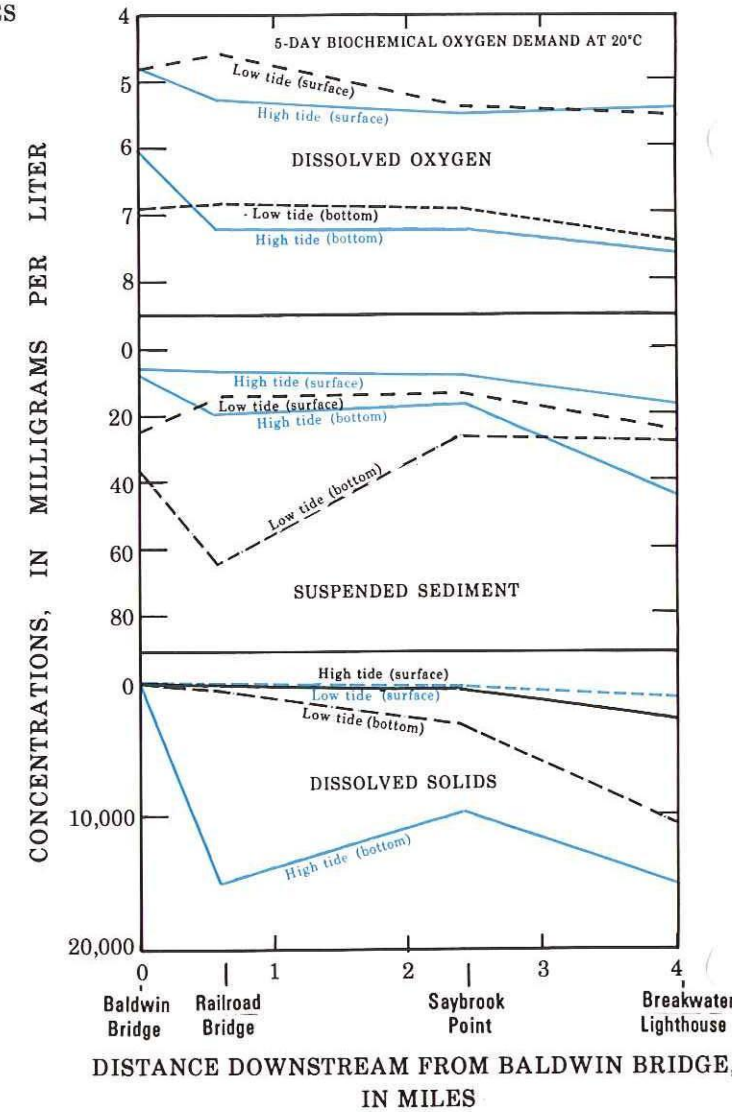


Figure 49.--Downstream changes in dissolved oxygen, biochemical oxygen demand, suspended sediment, and dissolved solids near the mouth of the Connecticut River on June 23, 1972

MAN'S EFFECT ON WATER QUALITY

The sources of pollution differ between urban and rural areas. In urban areas the sources are mainly treated industrial and domestic wastes that are concentrated in a few areas. The discharges of these wastes are generally continuous though the rate and composition may vary. Some indicators of domestic pollution are fecal coliform bacteria (indicative of human wastes) and fecal-streptococcal bacteria (found in human and animal wastes). Total coliform bacteria include enteric fecal coliform and natural soil bacteria. The ratios of fecal coliform to fecal streptococci, (Geldreich, 1966) indicate the presence of wastes from warm-blooded animals. In rural areas, the sources are domestic and agricultural in origin, and the discharges to streams are not as concentrated or as continuous. However, future industrial development is likely in rural areas along streams near major road arteries, such as those along the Falls River at Essex (See plate A).

Urban areas receive drinking water mostly from reservoirs or aquifers in rural areas outside the city limits and dispose of the waste water via sewage lines to sewage treatment plants. In rural areas, unconsolidated and bedrock aquifers may be contaminated by effluents from leach fields, industrial waste disposal and storage, as well as by runoff from highways and agricul tices. Since homes in rural settings depend almost exclusively on these aquifers for water supply, contamination can have severe impacts locally.

In Urban Areas

The Mattabesset River basin contains the industrialized cities of New Britain, drained mostly by Willow Brook; and Middletown, drained mostly by the Coginchaug River (fig. 50). Results of analyses of water samples collected in this basin on August 26 and 27, 1971, show that Willow

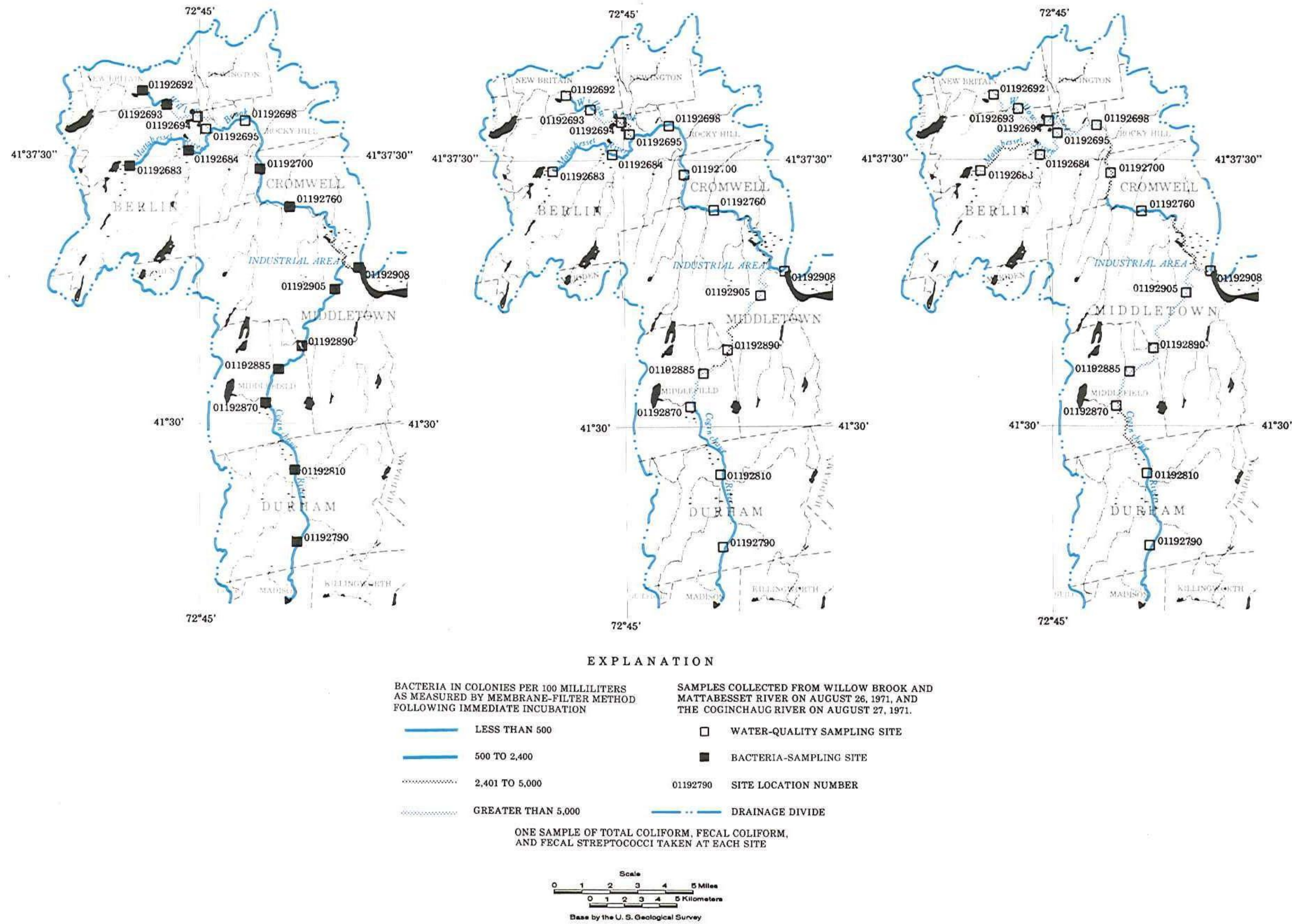


Figure 50.—Ranges in coliform and streptococci bacteria in samples from selected streams in the Mattabesset River basin

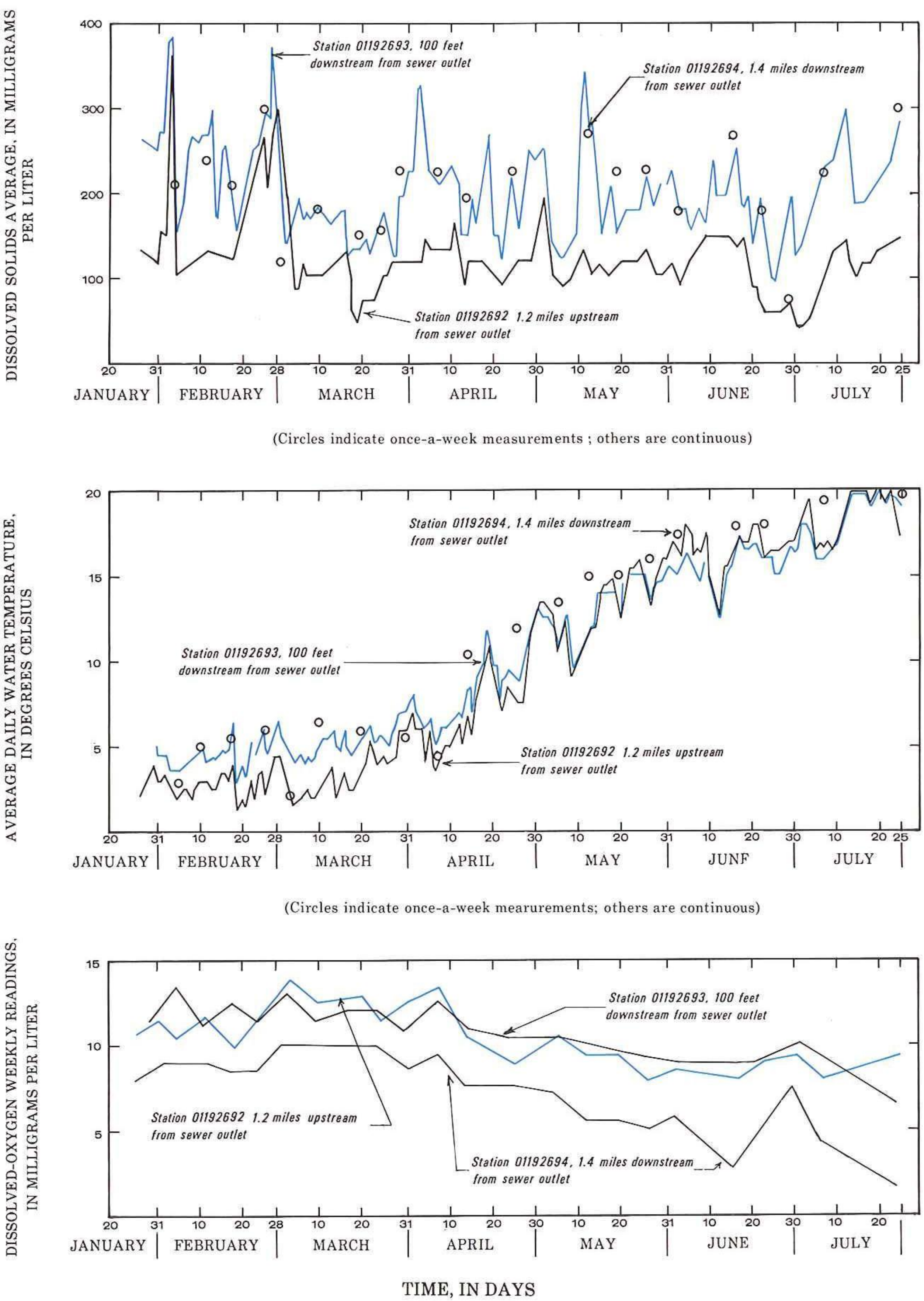


Figure 51.--Daily dissolved solids, water temperature, and dissolved oxygen at selected locations above and below a sewer outlet on Willow Brook during 1972

Brook and the lower part of the Coginchaug River had high concentrations of bacteria (table 25 and fig. 50). Figure 50 shows that the high concentrations of bacteria from Willow Brook were significantly reduced by the Mattabesset River. Weekly measurements of dissolved oxygen in Willow Brook during 1972 (fig. 51) show critical oxygen depletions at Station 01192694, with concentrations less than 5 mg/L for many days during the period June 7 - July 25, 1972.

Main stem of Mattabesset River and Coginchaug River.--Results of the bacteriological sampling of August 26-27, 1971 are shown in figure 50. Figure 50 and table 25 show that Willow Brook had more than 5,000 colonies per 100 milliliters of fecal-coliform bacteria downstream from station 01192693 on August 26, 1971, indicating human wastes. More than 5,000 colonies per 100 milliliters of fecal streptococci were recorded in the Coginchaug River downstream from station 01192870 and in Willow Brook downstream from station 01192693. The fecal streptococci in the Coginchaug River may be derived from animal wastes in farming areas, whereas those in Willow Brook are probably due to combined sanitary and storm-sewer discharges.

Increases in total dissolved solids, nitrite, ammonia, nitrate, phosphate, biochemical oxygen demand, and bacteria in the Mattabesset River at its confluence with Willow Brook (fig. 52) clearly show the effects of Willow Brook on the water quality. The only decrease in concentration is that of dissolved oxygen. Farther downstream, near the mouth of the Mattabesset River at station 01192908, increases in ammonia, iron, biochemical-oxygen demand, and bacteria, and a corresponding decrease in dissolved oxygen, show the effects of the Coginchaug River. Analyses of minor-metal constituents in the Mattabesset River basin (table 26) show few or no metal wastes from industrial processes. The major water-quality problems in the Mattabesset River appear to be from domestic wastes entering from Willow Brook. The ammonia, biochemical-oxygen demand, and bacterial increases near the mouth of the river probably represent animal wastes from the Coginchaug River, that are flushed from farming areas and storm sewer discharge in Middletown.

Table 25.--Chemical, physical, and bacteriological characteristics of water from tributaries of the Connecticut River affected by man

Station No.	Stream and location	Date of collection	Time (e.s.t.)	Dissolved oxygen at indicated temperature (mg/L)	Water temperature (°C)	Biochemical oxygen demand (5-day at indicated temperature) (mg/L)	(°C)	Specific conductance (micromhos at 25°C)	pH	Coliform bacteria (Colonies per 100 ml) Total	Fecal	Streptococcal
01192683	Mattabesset River near Kensington	8-26-71	0715	8.5	17.8	1.6	20	246	7.7	3,200	240	800
01192684	Mattabesset River at Berlin	8-26-71	0730	7.3	18.2	1.2	20	255	7.4	13,000	70	270
01192692	Willow Brook at New Britain	8-26-71	0745	9.5	16.3	2.6	20	340	7.6	16,000	820	1,100
01192693	Willow Brook near New Britain	8-26-71	0800	6.8	17.5	9.3	20	530	8.2	160,000	60,000	17,000
01192694	Willow Brook at Berlin	8-26-71	0815	1.75	19.5	9.6	20	450	7.1	70,000	20,000	4,200
01192695	Willow Brook at Berlin	8-26-71	0830	2.4	19.4	6.0	20	480	7.2	40,000	11,000	4,700
01192698	Mattabesset River at Berlin	8-26-71	0900	6.2	20.0	3.0	20	-	-	-	-	-
01192700	Mattabesset River at East Berlin	8-26-71	0915	8.8	20.0	2.4	20	400	7.6	3,600	530	42
01192760	Mattabesset River near Westfield	8-26-71	0940	8.5	21.5	1.6	20	-	-	-	-	-
01192790	Coginchaug River near Durham	8-26-71	1025	11.4	19.0	1.0	24.5	205	6.9	1,500	800	780
01192810	Coginchaug River at Durham	8-26-71	1040	5.8	20.0	-		226	6.6	2,000	580	620
01192870	Coginchaug River at Middlefield	8-26-71	1100	5.0	21.0	1.3	20.3	210	7.2	3,800	200	440
01192885	Coginchaug River at Rockfall	8-26-71	1100	8.9	19.0	-		241	7.2	6,000	700	6,000
01192890	Coginchaug River at Rockfall	8-26-71	1125	10.9	20.0	1.4	22.5	240	7.5	5,500	830	2,500
01192905	Coginchaug River at Middletown	8-26-71	1150	8.5	22.0	1.2	23.0	225	7.3	12,000	2,000	10,000
01192908	Mattabesset River at Middletown	8-26-71	0955	6.4	24.6	3.7	20	170	7.5	29,000	5,000	860
01194730	Wrights Pond at Pond Meadow	8-30-71	0950	9.3	26.0	-		-	-	-	-	-
01194732	Falls River at Ivoryton	8-30-71	1025	6.8	21.2	-		-	-	-	-	-
01194739	Falls River at Ivoryton	8-30-71	1040	6.3	22.5	-		-	-	-	-	-
01194742	Mill Pond on Falls River at Centerbrook	8-30-71	1100	6.75	25.0	-		-	-	-	-	-
01194745	Falls River at Essex	8-30-71	1125	5.3	24.5	-		-	-	-	-	-

Table 26.--Analyses of minor metals in water samples collected in the Mattabesset River basin, August 26, 1971

[Concentrations in milligrams per liter]

Constituent	Station number and name				Upper limit in raw water used for drinking 1/
	01192683 Mattabesset River near Kensington	01192695 Willow Brook at Berlin	01192700 Mattabesset River at East Berlin	01192908 Mattabesset River at Middletown	
Aluminum (Al)	0.019	0.025	0.011	0.020	-
Barium (Ba)	.067	.120	.087	.023	1.0
Beryllium (Be)	2/<.0006	<.001	<.0008	<.0004	-
Bismuth (Bi)	<.004	<.007	<.005	<.003	-
Boron (B)	.096	.220	.140	.030	-
Cadmium (Cd)	<.035	<.065	<.050	<.025	.01
Chromium Cr^{+6})	<.004	<.007	<.005	<.004	.05
Cobalt (Co)	<.003	<.005	<.004	<.002	-
Copper (Cu)	.005	.005	.005	.005	3/0.5 to 1.0
Germanium (Ge)	<.004	<.007	<.005	<.003	-
Lead (Pb)	.003	.007	<.004	<.002	.05
Lithium (Li)	<.010	.010	<.010	<.010	-
Molybdenum (Mo)	.001	.002	.001	.0007	-
Nickel (Ni)	.003	.005	.003	.011	-
Gallium (Ga)	<.0008	<.002	<.001	<.0005	-
Silver (Ag)	<.0002	<.0003	<.0003	<.0001	.05
Strontium (Sr)	.130	.450	.360	.130	-
Tin (Sn)	<.004	<.007	<.005	<.003	-
Titanium (Ti)	<.003	<.005	<.004	<.002	-
Vanadium (V)	.002	.003	.003	.004	-
Zinc (Zn)	<.240	<.420	<.350	<.150	-
Zirconium (Zr)	<.006	<.010	<.008	<.004	-

1/ Recommended by Connecticut General Assembly (1975).
2/ Symbol < indicates "less than".
3/ Depends on type of treatment.

Downstream changes in chemical and biological constituents were also measured in Willow Brook on August 26, 1971. Effluents entered this stream near station 01192693, resulting in large increases in coliform bacteria and subsequent oxygen depletion (fig. 53). The critical oxygen depletion occurred at station 01192694 and resulted in a dissolved-oxygen concentration less than 2 mg/L. The sewage effluent entering at station 01192693 consisted almost entirely of domestic wastes.

Downstream variations in water quality in the Coginchaug River are shown in figure 54.

Increases in total coliform bacteria, iron, manganese, and phosphate between stations 01192790 and 01192870 were probably caused by outflow from Durham Meadow swamp (See plate A). Downstream from the swamp, dissolved oxygen was at its lowest level. Between stations 01192870 and 01192885, all forms of bacteria measured, along with dissolved solids, had increased; these increases may be due to effluents entering near Ellen Doyle Brook. Bacteria, iron, phosphate, manganese, ammonia, and nitrite increased markedly between stations 01192890 and 01192905, apparently, because of storm-sewer discharges in the Middletown area.

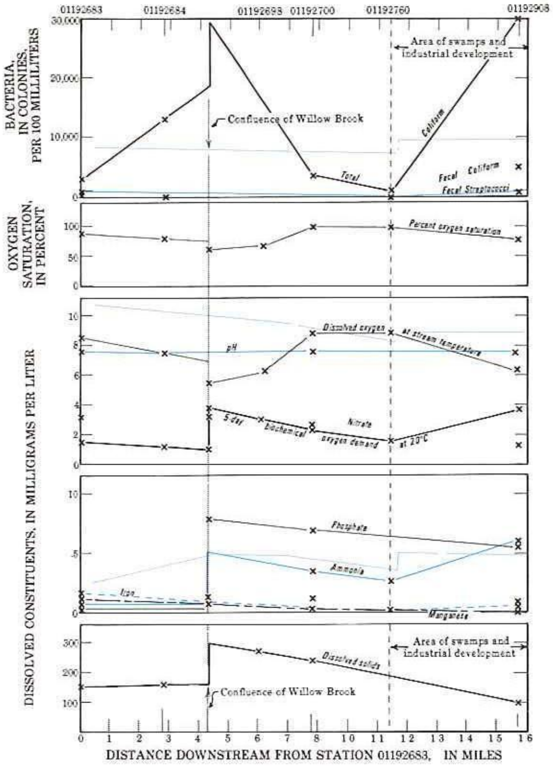


Figure 52.--Downstream changes in chemical and biological constituents in the Mattabesset River on August 26, 1971

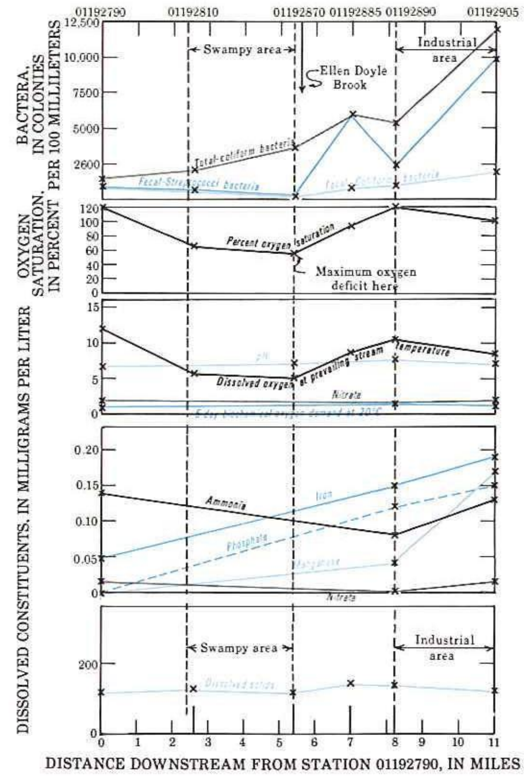


Figure 54.--Downstream changes in chemical and biological constituents in the Coginchaug River on August 27, 1971

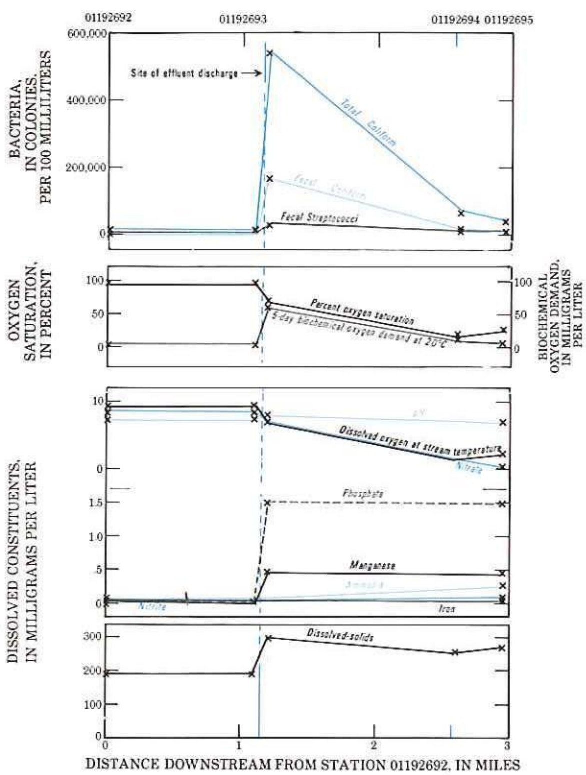


Figure 53.--Downstream changes in chemical and biological constituents in Willow Brook on August 26, 1971

Willow Brook.--Because effluent discharges vary with time, continuous measurements of chemical constituents in Willow Brook from station 01192692 to 01192695 were made over a period of six months in 1972 (fig. 55 and table 27). The effluents entering from a storm sewer and sanitary sewer line at station 01192693 and from discharge of leachates originating in town dumps upstream and downstream from station 01192694.

Depletion of dissolved oxygen is shown in figure 55 for different months and stream discharges. The critical depletion occurs at station 01192694, and oxygen has its lowest saturation value during the summer when stream discharge is low and water temperature is high. The dissolved-solids concentration at stations 01192693 and 01192694 was higher than at station 01192692 because domestic and industrial wastes entered 100 feet upstream from station 01192693. In late winter and early spring, the stream temperature was higher at station 01192693 than at 01192692 because the sewage was warmer than the stream, but in late spring and summer, the sewage was cooler than the stream. Dissolved-oxygen concentrations at all three sites were lowest in the summer owing to warmer stream temperature, and the oxygen values at station 01192694 were always the lowest as a result of oxygen depletion by bacterial decomposition between stations 01192693 and 01192694. The oxygen values were below 5 mg/L at station 01192694 three times during the period of

Table 27.--Chemical, physical, and biological characteristics of water in Willow Brook

(Analyses of samples from three sites in the basin collected from April to July 1972)
(Constituents in milligrams per liter, mg/L, except as noted)

Constituent or property	Station number, location on Willow Brook, and date of collection								
	01192692 at New Britain			01192693 near New Britain			01192694 near Berlin		
	4-25-72	5-26-72	7-25-72	4-25-72	5-26-72	7-25-72	4-25-72	5-26-72	7-25-72
Discharge (ft^3/s)	7.0	6.0	2.6	-	-	-	-	-	-
Silica (SiO_2)	-	10	13	-	13	15	-	-	-
Iron (Fe)	-	0.2	0.07	-	0.38	0.25	-	-	-
Manganese (Mn)	-	.02	.02	-	.11	.16	-	-	-
Calcium (Ca)	-	31	31	-	30	37	-	-	-
Magnesium (Mg)	-	4.3	8.5	-	7.3	12	-	-	-
Sodium (Na)	-	6.5	9.1	-	24	3.2	-	-	-
Potassium (K)	-	.6	.8	-	36	4.6	-	-	-
Ammonia (NH_4)	.54	-	.19	4.1	-	12	2.2	-	1.8
Bicarbonate (HCO_3)	-	50	89	-	89	170	-	-	-
Sulfate (SO_4)	-	19	24	-	36	48	-	-	-
Chloride (Cl)	-	15	22	-	33	42	-	-	-
Fluoride (F)	-	.3	.1	-	.6	.4	-	-	-
Nitrite (NO_2)	.04	-	.05	.27	-	.02	.12	-	.27
Nitrate (NO_3)	4.0	4.0	7.5	4.9	16	.0	4.4	-	2.6
Organic nitrogen (N)	.64	-	.44	1.1	-	6.5	1.6	-	1.6
Total phosphorous (PO_4)	.05	-	.18	3.8	-	15	.66	-	1.0
Dissolved solids (sum)	-	103	161	-	207	312	-	-	-
Hardness as $CaCO_3$ (calcium, magnesium)	-	65	112	-	105	142	-	-	-
Noncarbonate hardness as $CaCO_3$	-	24	39	-	32	2	-	-	-
Specific conductance (micromhos at 25°C)	- 185	184 208	280 275	- 360	384 375	522 480	- 375	- 395	- 500
pH laboratory (units)	-	7.4	8.0	-	6.7	7.0	-	-	-
pH field (units)	7.3	-	7.1	7.8	-	7.1	7.5	-	6.6
Water temperature (°C)	8.5	14.0	17.0	11.5	15.0	19.0	12.0	15.0	22.5
Dissolved oxygen	9.7	8.2	9.6	10.2	8.7	6.0	7.6	4.6	1.5
Oxygen saturation (percent)	82.8	78.8	99.0	92.2	85.3	64.5	70.4	45.1	17.2
Total coliform bacteria[1/] (colonies per 100 milliliters)	2,100	-	1,000	620,000	-	1,700,000	300,000	-	440,000
Fecal-coliform bacteria (Colonies per 100 milliliters)	440	-	520	200,000	-	840,000	30,000	-	24,000
Fecal-streptococcal bacteria (Colonies per 100 milliliters)	260	-	640	84,000	-	88,000	28,000	-	10,000

1/ Immediate incubation by membrane filter method, includes fecal-coliform and soil bacteria.

observation. Analyses of chemical constituents are given for three dates at all three stations (table 27).

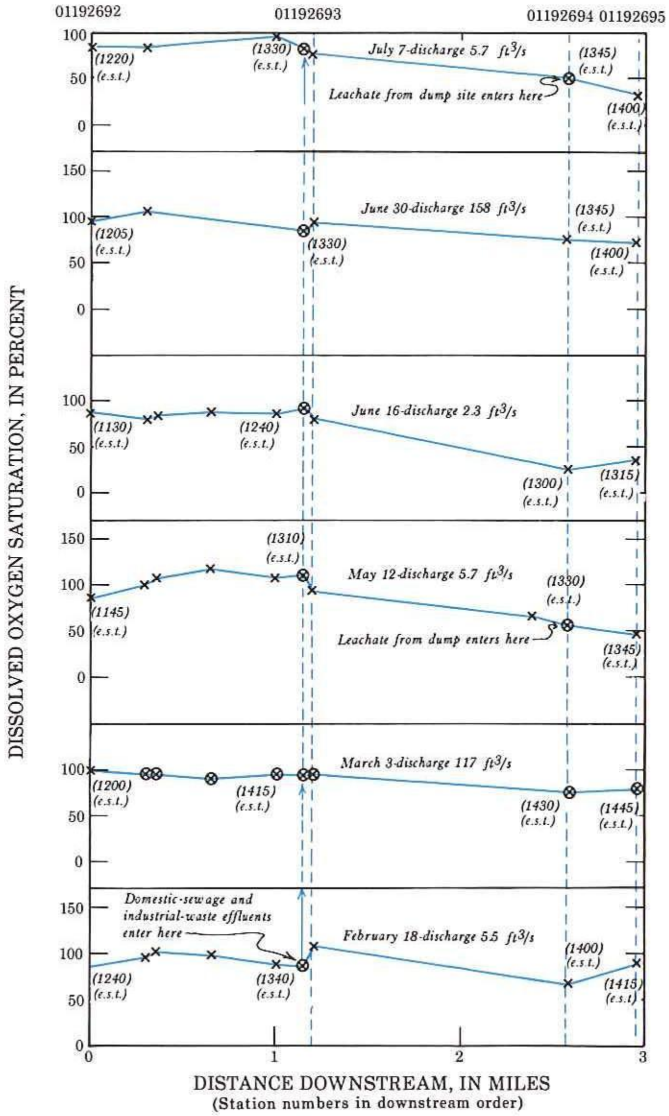


Figure 55.--Downstream changes in dissolved-oxygen saturation in Willow Brook during 1972

In Rural Areas

Water quality in streams draining rural areas may be degraded by highway or road runoff, industrial effluents, and agricultural runoff. Undesirable changes in ground-water quality are likely to be observed in areas where roads have been frequently salted, where there are numerous septic leach fields, or where land has been heavily fertilized.

Streams.--Streams near highways commonly have high concentrations of sodium and chloride. An example is Falls River in Essex, near Routes 144 and 9 (plate A). Figure 56 shows the concentrations of sodium and chloride at two sites on this stream. Station 01194730 is slightly north of Route 144 and site 01194742 is 4.15 miles downstream; most of the intervening reach is parallel to Route 144.

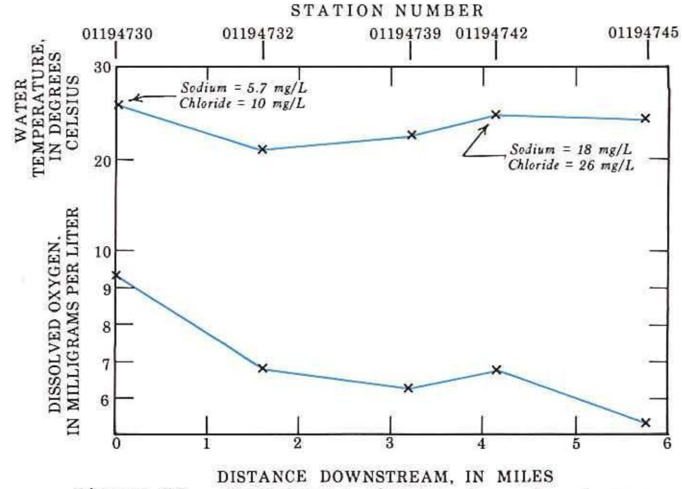


Figure 56.--Downstream changes in water temperature and dissolved-oxygen concentration in Falls River on August 30, 1971

Aquifers.--Ground-water quality is commonly related to the well's distance from potential sources of contamination, the type and thickness of overburden, the depth to the saturated zone, and to the type of well construction. Where the overlying unconsolidated deposits are thin, wells close to sources of pollution that are not tightly sealed into unweathered bedrock are vulnerable to pollution. High concentrations of nitrate in ground water may be derived from on-site septic systems or fertiziler application. The frequency of occurrence of specified nitrate concentrations in ground water is shown in table 28. Water from wells tapping coarse-grained stratified drift shows a marked decrease in nitrates when the length of casing is greater than 60 feet. Water from wells tapping bedrock shows a marked decrease in nitrates when the overlying unconsolidated deposits are equal to or greater than 60 feet and when compared to wells tapping coarse-grained stratified drift.

Table 28.--Factors affecting nitrate content of ground water near pollution sources

(Nitrate in water from wells is related to thickness of overburden, length of casing, and sealing of casing in bedrock)

Type of aquifer	Length of casing (in feet)	Percent of wells having nitrate concentrations, as indicated, in milligrams per liter (mg/L) <5 (mg/L)	>5 (mg/L)	>45 (mg/L)	Median No. of wells	Median Milligrams per liter
All unconsolidated deposits	≤60	39	61	0	18	5.2
Coarse-grained stratified drift	>60	73	27	0	15	.4
	(all wells combined)	55	45	0	33	3.5

Type aquifer	Length of casing set into bedrock (feet)	Thickness of overburden (feet	Percent of wells having nitrate concentrations, as indicated, in milligrams per liter (mg/L) <5 (mg/L)	>5 (mg/L)	>45 (mg/L)	Median No. of wells	Median Milligrams per liter
Bedrock	≤10	≤60	69	31	4	46	0.9
	≤10	>60	92	8	0	11	.2
	>10	≤60	66	34	3	29	1.8
	(all bedrock combined)		71	.9	3	86	.9

1/ (≤) Less than or equal to.
2/ (>) Greater than.

WATER USE

IN 1970

The total amount of water used in the study area in 1970 was approximately 255,600 million gallons. Of this, 98.3 percent was supplied by surface water (water in streams and reservoirs) and 1.7 percent by ground water. Streams supplied approximately 97 percent of the water used in the basin, most of which was used for cooling in steam-generated electric power plants. Domestic water use totaled 5,362 million gallons or 70 gallons per capita per day. The combined domestic, commercial and industrial usage, excluding cooling water, was 115 gallons per capita per day. Public systems accounted for 67 percent of the domestic needs and privately owned wells for 33 percent. Chemical and physical analyses of water from selected public systems are listed in table 29; public systems are described in table 30. Public supplies provided 23 percent of the water used in industry, if cooling water for power plants is excluded.

The source, use, and disposal of water in the basin in 1970 is shown in figure 57. Plate E shows the sites of all major withdrawals of water and the amounts withdrawn, along with which water is returned to streams or to the ground. Included in figure 57 are diversions into and out of the basin, and areas served by water and sanitary sewer lines. Most of the area served by water and sewer lines is west of the Connecticut River. Of the water distribution systems in the area, 31 percent are in the northwestern part and 65 percent are in the southern part. All of the sanitary sewer systems are in the northwestern part.

Chemical analyses of water from public supplies (table 29) show that 11 wells had sodium above the recommended limits for drinking water. Sodium concentrations in water samples from wells MF 173, CO 267, MB 2, WE 257, and MB 3 (pl. A) were more than 20 mg/L and are probably due to man's activities, whereas a sodium concentration of 33 mg/L and chloride less than 5 mg/L from water in well D 50 is believed to represent the natural quality of water from the sedimentary-bedrock aquifer. Five wells had nitrate concentrations equal to or greater than 10 mg/L; well ES 91 had 29 mg/L. Water samples from seven wells had iron concentrations above 1.0 mg/L and well CO 266 had 31 mg/L. In all, 19 wells and 3 reservoirs had concentrations of iron and manganese in excess of 0.3 and 0.05 mg/L, respectively.

IN THE FUTURE

The population within the study area in 1970 was 210,380. Based on projections of the U.S. Water Resources Council (1968), and by interpolation and comparison of water use for all purposes, the combined usage of water is expected to rise from 24 million gallons per day (Mgal/d) in 1970 to 36 Mgal/d in the year 2000. Cooling-water usage for electric steam-generating plants was 669 Mgal/d in 1970, but in that year the Haddam Neck nuclear plant was shut down for refueling for 60 days. During a non-refueling year, cooling water usage would have been 745 Mgal/d. If regulation on use and water-quality requirements remain unchanged, cooling-water usage is expected to increase to 1,120 Mgal/d. This could substantially effect total water usage, which would then rise to 1,150 Mgal/d in the year 2000. Much of the water for cooling could come from the untapped aquifers in the Connecticut River Valley, and growing requirements for drinking and industrial water could also be supplied by increased pumpage from these aquifers. The amount of water necessary for use in the year 2000 probably can be provided by sources available in the study area.

Table 29.--Chemical and physical characteristics of water from principal public water-supply systems

(Constituents in milligrams per liter, except as noted. Analyses by the U.S. Geological Survey.)

Public water-supply system	Date of collection	Source F, finished water R, raw water Res., reservoir	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Detergents as MBAS	Dissolved solids (sum)	Bicarbonate alkalinity as $CaCO_3$	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	Temperature (°C)	pH (units)	Color (platinum cobalt units)
Connecticut General Assembly limits for raw drinking water (1975):			-	-	-	-	-	1/20	-	-	-	-	250	2.0	2/10	-	0.5	500	-	-	-	-	-	-	3/20-250
Besock Lake Water Co.	5-28-71	R-Well HB 1	18	1.3	.27	44	4.0	14	3.6	180	0.0	6.7	5.0	.1	.0	-	.03	184	148	126	0	302	12.0	8.0	-
	5-28-71	R-Well HB 2	12	.24	.0	23	2.5	8.6	2.5	62	.0	21	9.5	.1	2.6	-	.04	113	51	68	17	178	10.5	7.7	-
	5-28-71	R-Well HB 10	9.6	.32	.06	23	2.8	6.2	.6	38	.0	22	19	.1	2.6	-	.04	105	19	69	38	184	10.5	6.9	-
	5-28-71	R-Well MF 17	9.8	.60	.0	27	7.1	30	1.4	80	.0	35	46	.0	6.6	-	.05	203	66	97	31	366	11.5	7.3	-
Colchester Water Dept.	5-20-71	R-Well CO 266	8.0	4/31	4/.07	10	2.6	8.7	1.2	9	.0	13	17	.1	6.7	-	.01	72	7.4	36	28	139	10.5	6.2	3
	5-20-71	R-Well CO 267	8.1	1.8	-	35	9.5	30	4.1	74	.0	44	62	.0	3.5	-	.10	233	61	126	66	434	12.0	7.0	2
	5-20-71	R-Well CO 315	10	-	-	12	2.0	6.4	4.1	29	.0	22	6.3	.0	7.4	-	.04	84	24	38	14	138	11.0	7.2	2
	5-20-71	R-Well CO 316	13	4/ .07	4/.07	14	4.0	13	2.5	27	.0	24	19	.0	11	-	.03	114	22	51	29	191	9.6	6.6	1
Colchester Community Water Assoc.	5-20-71	R-Well CO 317	18	4/ .35	4/.07	32	15	38	4.6	20	.0	18	140	.1	10		.06	286	9.8	141	125	557	13.0	7.1	-
Connecticut Water Co.	6-8-71	R-Well CL 190	13	.60	.14	9.0	2.0	7.2	1.4	18	.0	14	12	.0	.4		.02	68	8.9	31	16	104	17.0	7.2	-
	6-8-71	R-Well G 370	14	.06	.46	20	5.6	7.3	1.2	40	.0	20	21	.0	3.5	-	.02	112	20	73	40	202	9.5	7.6	-
	6-15-71	R-Well CL 191	15	.28	.0	12	3.2	7.0	1.2	25	.0	14	12	.0	11	-	.03	87	12	43	23	135	11.0	7.1	-
	6-8-71	R-Well WE 257	30	3.5	.65	11	2.3	43	1.4	128	.0	10	15	1.8	1.8	-	.03	180	63	37	0	268	12.0	8.2	-
	6-15-71	R-Kelseytown Res.	4.5	.44	.05	6.0	1.1	4.7	1.7	10	.0	8.5	6.2	.0	.0	0.6	.03	38	4.9	20	11	59	20.5	6.8	14
	6-15-71	R-Waterhouse Pond	3.3	.34	.21	5.0	1.2	3.2	.7	4	.0	12	5.2	.0	.0	.0	.02	33	2.0	17	14	55	21.0	5.2	8
Durham Aqueduct Co.	5-25-71	R-Well MT 322	11	.26	.0	16	2.4	7.2	3.2	18	.0	20	21	.0	6.2	-	.04	96	8.9	50	35	163	10.5	7.1	-
	5-25-71	R-Spring MT 1SP	9.4	.88	.0	23	3.8	12	.9	33	.0	25	29	.1	6.2	-	.04	126	16	73	46	224	10.0	6.9	-
Durham Center Water Co.	5-25-71	R-Well D 50	9.4	4/ .05	4/.0	37	17	33	1.0	216	4.0	38	7.5	.5	1.8	-	.03	255	177	162	0	430	11.0	8.3	-
Forest Property Owners Assoc.	5-28-71	R-Well MB 2	19	2.3	.33	54	4.1	26	1.4	90	.0	46	64	.0	.0	-	.06	259	74	151	78	456	12.5	7.7	-
Lakewood Road Water Co.	6-4-71	R-Well EHM 364	0	.23	.0	4.0	.9	2.7	.5	8	.0	6.5	2.4	.0	.0	-	.01	31	3.9	14	7	39	8.5	6.9	-
Heritage Apts.	6-1-71	R-Well ES 90	10	.98	.10	14	2.9	14	2.6	11	.0	21	30	.0	10	-	.04	110	9.0	47	38	205	11.5	7.0	-
	6-1-71	R-Well ES 91	11	3.8	.08	15	4.0	11	2.6	14	.0	15	23	.0	29	-	.05	117	12	54	42	199	11.5	6.8	-
Lake Hayward Water Co.	6-4-71	R-Well EHD 316	19	.31	.10	18	2.5	6.9	2.7	58	.0	15	6.6	.1	.0	-	.02	99	29	55	8	154	11.0	7.9	-
Marlborough Gardens, Inc.	5-28-71	F-Well MB 3	24	.10	.08	22	5.0	40	4.5	130	.0	40	18	.1	.0	-	-	218	107	76	0	340	12.0	7.9	-
Meriden Water Dept.	6-10-71	R-Kenmore Res.	6.7	.16	.0	16	4.4	3.9	.6	50	.0	19	4.8	.0	.0	0.3	.03	80	25	58	17	143	22.0	7.3	12
	6-10-71	R-Merimere Res.	5.2	-	-	9.9	2.5	2.7	.2	25	.0	11	3.5	.0	.0	-	.02	47	12	35	15	91	20.5	7.2	6
Middletown Water Dept.	5-24-71	R-Well MT 319	8.2	.80	.32	17	2.6	9.4	.8	44	.0	17	12	.0	1.3	-	.03	90	22	53	17	155	7.5	7.5	-
	5-24-71	R-Well MT 320	6.5	.56	.32	13	2.2	8.6	.8	40	.0	12	9.7	.0	.4	-	.03	73	20	42	9	136	7.0	7.3	-
	5-24-71	R-Well MT 321	3.1	3.9	.20	13	2.1	11	3.3	36	.0	20	13	.1	.0	-	.08	84	18	41	12	154	-	7.1	-
	6-9-71	R-Laurel Res.	.3	.09	.0	15	2.3	5.8	.7	26	.0	23	9.4	.0	.0	.03	.03	69	21	47	26	130	24.0	7.1	7
	6-9-71	R-Mt. Higby Res.	5.6	.10	.05	7.1	2.7	7.6	.3	14	.0	17	14	.0	.0	.03	.03	61	6.9	29	17	112	22.0	7.0	6
New Britain Water Dept.	6-10-71	R-Shuttle Meadow Res.	4.8	.05	.0	10	2.2	4.1	.5	18	.0	13	7.4	.0	.9	.0	.03	52	8.9	34	19	88	21.0	7.1	3
	6-10-71	R-Wasel Res.	7.8	.09	.04	4.0	1.2	2.9	.5	10	.0	9.7	3.6	.0	.4	.03	.02	30	4.9	15	6.7	49	21.0	6.5	9
New Haven Water Dept.	6-9-71	R-Hammonasset Res.	1.7	.16	.06	5.0	1.2	4.9	1.6	4	.0	11	5.4	.0	.0	.0	.04	33	2.0	17	14	52	21.0	6.2	21
		R-Menunketuck Res.	7.0	.03	.03	10	3.3	3.5	.3	30	.0	14	3.8	.0	.0	.06	.02	57	15	39	14	95	23.0	7.1	6

1/ Treated water
2/ Nitrite and nitrate as nitrogen
3/ Based on type of treatment
4/ Samples collected 10-8-71

Table 30.--Characteristics of principal public water-supply systems

Public water supply	Town supplied	Total popu-lation served	Primary source of water: Name or source	Primary source of water: Percent of supply	Auxiliary or emergency source	Treatment plant: Type used	Treatment plant: Name or site	Treatment plant: Capacity (Mgal/d)
Abbey Estates	Hebron	100	Well	100	None	None	None	None
Beechwood Mobil Homes	Killingworth	377	Wells	100	None	None	None	None
Beseck Lake Water Co.	Hebron Lebanon Middlefield	400 500 500	Wells	100	None	None	None	None
Colchester, city of, Water Dept.	Colchester	3,450	Wells	100	Wells	Sedimentation Iron Chlorine	None	None
Connecticut Valley Hospital	Middletown	5,000	Reservoirs	100	None	Chlorine	None	None
Connecticut Water Co., Guilford-Chester Div. Chester Div.	Chester Clinton Deep River Essex Guilford Madison Old Saybrook Westbrook	42,556	Upper Reservoir Lower Reservoir Turkey Hill Reservoir Deep Hollow Reservoir Deuses Pond Killingworth Reservoir Kelseytown Reservoir Guilford Well Dennison Wells Westbrook Well Clinton Well	20.5 29.0 16.0 2.5 16.0 16.0	Rettick Wells Weiss Well Brookside Well	Chlorine Calgon Fluoride 2/ Lime 3/ Caustic Soda 4/ Iron and manganese removal 5/ Sodium silicate 6/	None	None
Cromwell Fire Dist.	Cromwell	1/2,338	Dividend Brook Wells	100	Nooks pond Shop Pond Shanty Pond Ice House Pond Wells	Chlorine Flouride	None	None
Cromwell Hill Apts.	Cromwell	700	Well Spring	100	Wells	None	None	None
Durham Aqueduct Co.	Durham	100	Spring	100	Well	None	None	None
East Berlin Fire Dist.	East Berlin	1,900	New Britain Water Dept	100 100	None	Treated by New Britain	New Britain	12.0
Edgemere Apts.	East Hampton	150	Well	100	None	None	None	None
Colchester Community Water Assoc.	Colchester	70	Well	100	None	None	None	None
Forest Property Owners Assoc.	Marlborough	150	Well	100	None	Iron and manganese	None	None
Five Field Dev. (HMS)	Madison	120	Well	100	Well	Chlorine	None	None
Lakewood Road Water Co.	East Hampton	140	Well	100	Well	None	None	None
Hammonasset Park	Madison	Variable	Connecticut Water Co.	100	None	Treated by the Conn. Water Co.	None	None
Heritage Apts.	Essex	208	Well	100	Well	None	None	None
Hillside Corp., Inc.	Marlborough	128	Wells	100	None	None	None	None
Kensington Fire Dist.	Kensington	7,500	New Britain Water Dept.	100	None	Treated by New Britain	12.0	None
Lake Hayward Water Co.	East Haddam	1,600	Wells	100	None	None	None	None
Laurel Hieghts Water Assoc.	Marlborough	90	Wells	100	None	None	None	None
Marlborough Gardens, Inc.	Marlborough	160	Well	100	None	Sedimentation Iron and manga-nese removal	None	None
Meriden Water Dept.	Berlin	80			Kensington Well			
	Meriden	1/80	Hallmere Reservoir Kenmere Reservior Merimere Reservoir	100		Coagulation Filtration	2/Elmere Filter Plant, Meriden	7.0
Metropolitan Dist. Commission	Newington Rocky Hill	1/11,000 1/ 600	Nepaug Reservoir Parkhamsted Reservoir		West Hartford Reservoirs 2-6	Aeration Filtration Sedimentation Chlorine Lime Fluoride Calgon	Farmington Ave., West Hartford	62.5
Middlesex State Jail	Haddam	Variable	Well	100	None	None	None	None
Middletown, city of, Water Dept.	Middletown	32,000	Mount Higby Reservoir Laurel Brook Reservoir Wells	53.0 47.0	Roaring Brook	Chloride Fluoride Iron and manganese removal 1/	River Road Middletown	3.2
New Britain, city of, Water Dept.	New Britain Newington Berlin	1/55,121	Shuttle Meadow Reservoir Panther Swamp Reservoir Wolcott Reservoir Whigville Reservoir Coppermine Brook Whites Bridge Wells 4/	85.2 14.8	Nepaug Reservoir	Aeration Coagulation Sedimentation Filtration Activated carbon Chlorine Fluoride	Shuttle Meadow Ave., New Britain	12.0
New Haven Water Co.	None	None	Hammonasset Reservoir Menunkatuck Reservoir	1/15.7 1/84.3	None	None	None	None
Portland, city of, Water Dept.	Portland	1/ 1,700	Portland Reservoir Well	95.6 4.4	None	Chlorine Calgon	None	None
Pinewood Estates	Guilford	28	Well	100	Well	None	None	None
Worthington Fire Dist.	Berlin	6,967	New Britain Water Dept.	100	None	Treated by New Britain	New Britain	12.0

Table 30.--Characteristics of principal public water-supply systems.--Continued

Raw-water storage (million gallons)	Finished-water storage (thousand gallons)	Movement and use of water in basin in 1970: DIVERSION to basin (million gallons)	DIVERSION from basin (million gallons)	Total use (million gallons)	Total use of public-supplied water (percent): Domestic	Commercial	Industrial	Municipal and leakage	Remarks3/
None	None	None	None	24	100	--	--	--	
None	None	None	None	8.6	100	--	--	--	
None	18	None	None	16.6	100	--	--	--	
None	450	None	None	86.1		1/94.0	--	6.0	1/ Domestic and commercial.
None	None	None	None	110	1/100	--	--	--	1/ Institutional.
21.0 172 180 55.0 6.0 222 18.9	3,860	None	None	1,814		1/64.6	18.1	17.3	1/ Domestic and commercial. 2/ Only in Guilford Division. 3/ Waterhouse Pond. 4/ Kelseytown Reservoir. 5/ Guilford Well. 6/ Westbrook Well.
9.3	1,200	95.1	None	2/95.1	56.4	32.7	10.2	.7	1/ Population served in basin. 2/ Based on population served in basin.
None	17	None	None	9.0	100	--	--	--	
None	15	None	None	2.4	100	--	--	--	
None	50	None	None	5.7	100	--	--	--	
None	None	None	None	1/49.3					1/ Included in New Britain usage.
None	None	None	None	1.7	100	--	--	--	
None	10	None	None	3.7	100	--	--	--	
None	None	None	None	4.4	100	--	--	--	
None	1	None	None	1.7	100	--	--	--	
None	None	None	None	18.4	1/100	--	--	--	1/ Recreational.
None	10	None	None	4.9	100	--	--	--	
None	None	None	None	3.0	100	--	--	--	
None	None	None	None	1/450	--	--	--	--	1/ Included in New Britain usage.
None	50	None	None	19.0	100	--	--	--	
None	3.22	None	None	2.3	100	--	--	--	
None	10	None	None	4.4	100	--	--	--	
140 133 357	12,500	None	3/1,058	3.4	100	--	--	--	1/ Population served in basin. 2/ Only for water water to Meriden. 3/ To Meriden.
9,494 31,761 1,277	33,300	2/602	None	2/602	68.5	24.1	1.5	5.9	1/ Population served in basin. 2/ Based on population served in basin.
None	60	None	None	2.1	100		--	--	
374	3,000	None	None	1,166		2/77.1	19.0	3.9	1/ Wells only. 2/ Domestic and commercial.
1,290 900 170 64 9,494	8,900	1,980	None	2/2,325		3/73.5	10.0	16.5	1/ Population served in basin includes East Berlin, Kensington, and Worthington Fire Districts. 2/ Based on population served in basin. 3/ Domestic and commercial. 4/ Chlorine and fluoride only.
1,400 203	None	None	354 1,904	None	--	--	--	--	1/ Percent diverted from basin.
150	1,500	2/75.4	None	2/75.4	73.8	18.4	4.2	3.6	1/ Population served in basin. 2/ Based on population served in basin.
None	10	None	None	.8	100	--	--	--	
None	None	None	None	1/87.7	--	--	--	--	1/ Included in New Britain percentage.

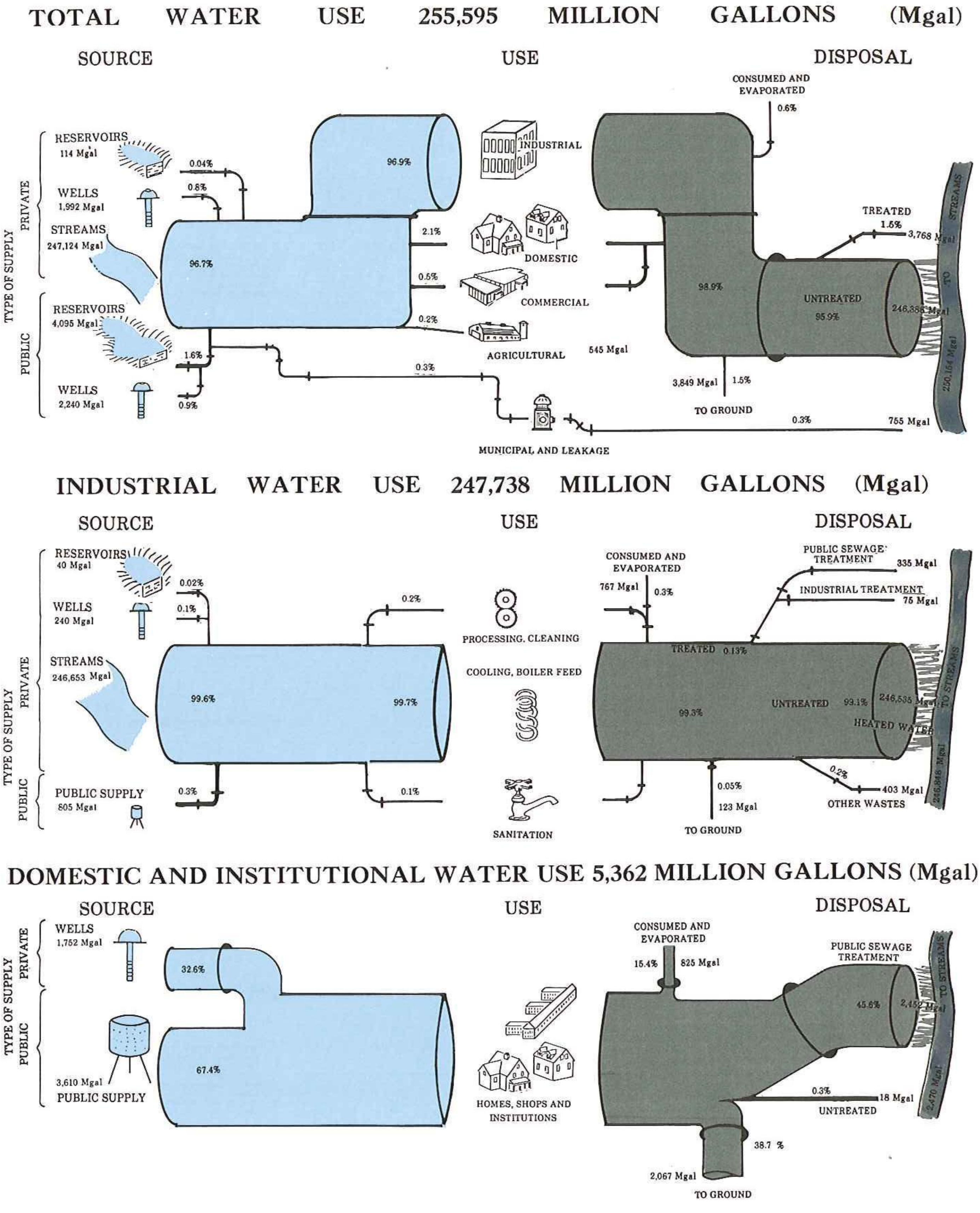


Figure 57.—Source, use, and disposal of water in the study area in 1970

ABBREVIATIONS

°C - degrees Celcius (Centigrade)

Mgal/yr - million gallons per year

ft^3/s - cubic feet per second (previous reports in the series used the abbreviation cfs)

ft^3/mi^2 - cubic feet per second per square mile (previous reports in the series used the abbreviation csm)

ft^3/d - cubic feet per day (previous reports in the series used the abbreviation cu ft/day)

°F - degrees Fahrenheit

fig. - figure

ft - feet, foot

gal/d - gallons per day (previous reports in the series used the abbreviation gpd)

gal/min - gallons per minute (previous reports in the series used the abbreviation gpm)

in - inches

lsd - land surface datum

Mgal/d - million gallons per day (previous reports in the series used the abbreviation mgd)

mg/L - milligrams per liter

mi - miles

mL - milliliters

mm - millimeters

p. - page

pl. - plate

ppm - parts per million

R.I. - recurrence interval

ft^2 - square feet (previous reports in the series used the abbreviation sq ft)

mi^2 - square miles (previous reports in the series used the abbreviation sq mi)

ug/L - micrograms per liter

Mmho - micromhos

NGVD - National Geodetic Vertical Datum of 1929

EQUIVALENTS

°C = (°F - 32) x 0.555

1 ft^3/s - 646,000 gal/d = 0.646 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 Mgal = 2.32 million cubic feet

1 Mgal/d = 694 gal/min = 1.55 ft^3/s

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

1 mm = 0.001 meter = 0.039 in

Hydraulic conductivity (ft/d) x 7.48 = coefficient of permeability in $gal/d/ft^2$

Transmissivity (ft^2/d) x 7.48 = coefficient of transmissibility in gal/d/ft

GLOSSARY

Acid: A substance containing hydrogen, which dissociates to yield excess hydrogen ions when dissolved in water. Acid solutions can dissolve many metals.

Alluvium: Sediment composed of various proportions of gravel, sand, silt, clay, and organic matter deposited by streams.

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

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

Base: A substance containing hydrogen and oxygen, which dissociates to form hydroxide ions when dissolved in water. Basic solutions neutralize acidic solutions.

Bedrock: The solid rock, commonly called "ledge," that forms the earth's crust. In the report area, it is locally exposed at the surface but more commonly is buried beneath a few inches to as much as 200 feet of unconsolidated deposits.

Biochemical oxygen demand: The amount of oxygen required by bacteria while stabilizing decomposible organic matter under aerobic conditions.

Buildup: The rising of the water level or the equivalent increase in the pressure of the water in a well. The opposite of drawdown.

Calcite: A common mineral composed of calcium carbonate ($CaCO_3$), which is the principal constituent of limestone and marble.

Calc-silicate rock: A metamorphic rock mainly consisting of calcium-bearing silicates.

Carbonate: A compound containing the radical CO_3.

Carbonate bedrock: Bedrock composed primarily of calcium and magnesium carbonate minerals.

Carbonate hardness: A measure of the amount of alkaline-earth cations effectively balanced by carbonate (and bicarbonate) anions.

Chemical quality of water: The quantity and kinds of material in suspension or solution and the resulting water properties.

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.

Coefficient of permeability: The rate of flow of water, in gallons per day, through a cross sectional area of 1 ft^2 of a saturated material under a hydraulic gradient of 1 foot per foot at a temperature of 16°C. Replaced by the U.S. Geological Survey with a new term--hydraulic conductivity (in this Glossary). Also, see "Equivalents" in preceding section.

Coefficient of transmissibility: The rate of flow of water at the prevailing water temperature, in gallons per day, through a vertical strip of an aquifer 1 foot wide extending the full thickness of the aquifer under a hydraulic gradient of 1 foot per foot. It is the product of the field coefficient of permeability and saturated thickness of an aquifer. Replaced by the U.S. Geological Survey with a new term--transmissivity (in this Glossary). Also, see "Equivalents" in preceding section.

Color unit: A standard of color of water determined by the platinum-cobalt method of measuring, with the unit being that produced by 1 mg/L of platinum in water. Results are conventionally expressed as units of color and not as mg/L.

Continuous-record gaging station: A site on a stream at which continuous measurements of stream stage are made by automatic equipment or are 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 igneous or metamorphic bedrock composed of closely interlocking crystals or crystal fragments.

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, aquifer, lake, or drainage basin, in 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; consists primarily of dissolved mineral constituents, but it may also contain organic matter and water of crystallization.

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

Drawdown: The lowering of water level or the reduction in the pressure of water caused by the withdrawal of water in a well.

Epilimnion: The top layer of water in a stratified lake, pond, or reservoir.

Equivalent weight: The number of parts (by weight) of a substance that combines with, or is otherwise chemically equivalent to, 8.0 parts (by weight) of oxygen.

Estuary: A body of water in which river water mixes with and measurably dilutes sea water.

Evapotranspiration: Discharge of water to the atmosphere by direct evaporation from water surfaces or moist soil and by transpiration from plants.

Fecal-coliform bacteria: Those organisms that ferment lactose with gas production within 24 hours at $44.5^{\circ}C$.

Fecal-streptococci bacteria: Include all streptococcal species that grow in brain-heart infusion broth at 45° and $10^{\circ}C$, or at $45^{\circ}C$ only.

Ferric iron: An oxidized or high-valence form of iron (Fe^{+3}) having a low solubility in water solutions. Formed from ferrous ions in water that combine with oxygen when exposed to air.

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

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, in bedrock: A break or opening 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.

Gneiss: A coarse-grained crystalline rock with alternating bands of granular and micaceous or elongate minerals.

Granite: A coarse-grained, light-colored, igneous rock.

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) pumping wells and other man-made structures.

Ground-water divide: A line on a water table or other potentiometric surface on each side of which the water table or ground water represented by that surface moves downward in a direction away from the line. In the vertical dimension, a plane or surface across which ground water does not 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; includes all natural ground-water discharge from a drainage area exclusive of ground-water evapotranspiration.

Ground-water recharge: The amount of water that is added to the saturated zone.

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

Hardness, of water: The property of water generally attributed to dissolved salts of the alkaline earths. Hardness has soap-consuming and encrusting properties and is expressed as the concentration of dissolved calcium carbonate required to produce the observed effect.

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 or source of recharge of an aquifer. There are two types: impermeable-barrier and line-source boundaries.

Hydraulic conductivity (K): 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. It is 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 conductivity is expressed as coefficient of permeability.

$$K = \frac{\text{gallons}}{\text{day ft}^2\text{ft/ft}} = \frac{\text{ft}^3}{\text{day ft}^2\text{ft/ft}} = \text{ft/day.}$$

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.

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

Image well: An imaginary well so placed with respect to a real well and nearest hydrologic boundary that by discharging or recharging it produces a ground-water divide or condition of no drawdown along the boundary position.

Impermeable-barrier boundary: The surface between an aquifer and adjacent impermeable material that terminates the aquifer. An example is the termination of permeable valley-fill deposits of sand and gravel against the bedrock valley walls. Its significant hydraulic feature is that ideally no ground water flows across it.

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

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

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

Isopleth: Line on a map connecting points at which a given variable has a specified constant value.

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

Lacustrine deposits: Sand, silt, or clay deposits produced by or formed in a lake and deposited on its bottom.

Line-source boundary: A boundary formed by a surface-water body that is hydraulically connected to an adjacent aquifer. Ideally there is no drawdown along such a boundary.

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 mean is an average of quantity.

Metalimnion: The middle layer of water in a stratified lake, pond, or reservoir; it contains the plane or planes of rapidly changing temperature.

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

Mho: The practical unit of electrical conductance equal to the reciprocal of the ohm, a unit of electrical resistance.

Micromho (Mmho): A unit of electrical conductance, equal to one-millionth of a mho.

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

Mineral content, of water: The dissolved inorganic substances, most of which are derived from the minerals in rocks. It is generally assumed to be equivalent to the dissolved solids unless substantial amounts of nonvolatile organic substances are present.

NGVD: National Geodetic Vertical Datum of 1929. Referred to in this report as "sea level" and in previous reports of the U.S. Geological Survey as "mean sea level."

Noncarbonate bedrock: Bedrock composed primarily of quartz and silicate minerals.

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

Overburden: All the various unconsolidated materials that overlie the bedrock.

Partially 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 concentrations. Ordinarily a pH value of 7.0 indicates that the water is at its neutral point; values lower than 7.0 denote acidity, those above 7.0 denote alkalinity.

Pollution: "Harmful thermal effect or the contamination or rendering unclean or impure of any waters of the State by reason of any wastes or other material discharged or deposited therein by any public or private sewer or otherwise so as directly or indirectly to come in contact with any waters" (Connecticut General Assembly, 1967, Public Act No. 57.

Porosity: The property of bedrock or unconsolidated material of containing voids or open spaces; it may be expressed quantitatively as the ratio of the volume of its open spaces to its total volume.

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

Quartz: A mineral (crystalline SiO_2). A common constituent of many rock types.

Reaeration: The mechanical process by which air is reabsorbed in water after deoxygenation from organic matter.

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.

Respiration: A sum total of the physical and chemical processes in an organism by which oxygen and carbohydrates are assimilated into the system and the oxidation products, carbon dioxide, and water are given off.

Runoff: That part of the precipitation that appears in streams. It is the same as streamflow unaffected by artificial diversions, storage, or other works of man in or on the stream channels.

Sandstone: A fine to medium-grained sedimentary rock, which in this basin, is composed principally of quartz and feldspar grains (arkose).

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

Saturated zone: The subsurface zone in which all open spaces are filled with water. The water table is the upper limit of this zone and the water in this zone is under pressure equal to or greater than atmospheric pressure.

Schist: A metamorphic rock with subparallel orientation of the visible micaceous minerals, which dominate its composition.

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

Sedimentary bedrock: A rock resulting from the consolidation of loose sediment that has accumulated in layers.

Sewage: Liquid or solid waste commonly carried off in sewers.

Shale: A fine-grained, laminated, sedimentary rock composed principally of clay-sized particles.

Siliceous: Containing abundant quartz or silica.

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 which a saturated rock or soil will yield by gravity to its own volume.

Storage coefficient, S: The volume of water a porous medium releases from or takes into storage per unit surface area of the medium per unit change in head; dimensionless.

Stratified drift: A predominantly sorted sediment laid down by or in meltwater from a glacier; includes sand and gravel and minor amounts of silt and clay arranged 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 horizontal layers of water with different temperatures in most deep openwater bodies.

Thermocline: The plane or planes of most rapid temperature change with depth in a stratified lake, pond, or reservoir. It is that part of the metalimnion 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.

Total coliform bacteria: Include all aerobic and facultative anaerobic gram-negative, non-spore-forming rods that ferment lactose with gas production within 48 hours at 35° C.

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 previous reports of this series, transmissivity is expressed as the coefficient of transmissibility (a term since abandoned by the U.S. Geological Survey).

Transpiration: The process whereby plants release water in vapor form 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.

Unsaturated zone: The zone between the water table and the land surface in which not all the open spaces are filled with water (except temporarily).

Volcanic bedrock: A generally finely crystalline or glossy igneous rock resulting from volcanic action at or near the earth's surface, either by being ejected explosively or extruded as lava.

Water table: The upper surface of the saturated zone.

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.

Wentworth grade scale: A grain-size classification system, based on particle diameter, the divisions of which are as follows: boulders, = 256 mm or larger; cobbles, 256 to 64 mm; pebbles, 64 to 4 mm; very fine gravel, 4 to 2 mm; very coarse sand, 2 to 1 mm; coarse sand, 1 to 0.5 mm; medium sand, 0.5 to 0.25 mm; fine sand, 0.25 to 0.125 mm; very fine sand, 0.125 mm to 0.063 mm; silt, 0.063 to 0.004 mm; clay, = 0.004 mm or smaller. This grade scale is used for sediment descriptions in this report.

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